PETROLEUM DEVELOPMENT AND TECHNOLOGY

1942

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and Petroleum

(INCORPORATED)

Volume 146

PETROLEUM DEVELOPMENT AND TECHNOLOGY

1942

PETROLEUM DIVISION

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COVERING THE YEAR 1941

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FOREWORD

THIS volume of TRANSACTIONS, Petroleum Development and Technology, 1942, is commended to our members. Since so many excellent papers were submitted at our meetings and to PETROLEUM TECHNOLOGY, space and funds necessitated a very critical selection.

During the past year a distinguished member of our Division, Mr. John Suman, served as president of the Institute and headed the group that attended our meetings at Tulsa, Los Angeles, and New York. Suffice to say that these meetings were among the most successful ever held by our Division and the caliber of the papers presented was high.

In January 1942, our own Dr. E. L. DeGolyer was given the John Fritz Medal, awarded jointly by the four Founder Engineering Societies. Dr. DeGolyer received this high honor for pioneering in geophysical exploration of petroleum deposits.

Never were the responsibilities placed upon the Petroleum Division greater than they are in this first year of our nation's participation in an actual "World War"—an all-out war—the outcome of which will decide whether democracy and free men may continue to exist. The successful prosecution of the science of war is dependent upon petroleum and its products—this war, and the peace that must inevitably follow, may largely be won by the Industry of which we are a part.

The aim and ambition of this Division, its officers and committees, have been to serve the members so that they may profit most from its functions—that aim and ambition for all must now be transcended into the winning of the war. With the calling of many of our members into government service, the duties of the remaining individuals are being multiplied. Harder work and less free time lie ahead. Scientific research and technical progress must not falter; to this end our local, sectional and national meetings must continue as agencies toward the dissemination of knowledge. The efficient operation of the Petroleum Industry, so essential to the war effort, is primarily in the hands of the members of our Division. We should be proud in the knowledge that all of our members, regardless of their battle stations in the armed services or within industry, are all-out for Victory.

Technical meetings are to be held at Austin, Texas, Oct. 29–31, inclusive, and at Los Angeles, Oct. 15 and 16. Preparations are well under way and exceptional programs are assured.

Appreciation is expressed of the splendid cooperation of all members of the Institute—the personnel of New York headquarters, committee chairmen, vice-chairmen, authors and members of the Division. Their continued interest and active participation augurs well for the future affairs of the A.I.M.E.

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In 1936 the Institute established the Anthony F. Lucas Gold Medal, to be awarded from time to time "for distinguished achievement in improving the technique and practice of finding and producing petroleum." These awards are sponsored by the Petroleum Division.

Captain Lucas was a pioneer in the oil industry, one of the early wildcatters and a leading mining and petroleum engineer. He was famous as the discoverer of Spindletop. He became a member of the Institute in 1895 and in 1913 was the first Chairman of the Petroleum and Gas Committee of the Institute, the forerunner of the present Petroleum Division. He also headed the Committee in 1914, 1917 and 1918.

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Chapter I. Production Engineering

Sampling Gas-condensate Wells

By J. M. Flaitz,* and A. S. Parks,† Members A.I.M.E.

(Dallas Meeting, October 1941)

Of the various methods of sampling gas-condensate wells, a method that secures a continuous representative sample of the well stream is desirable. Such a method, consisting of a sampling tube introduced into the well tubing, has proved satisfactory. The method is sufficiently accurate for operating and engineering problems. A portable testing apparatus can be used with the sampling tube to obtain data useful in studying the economic and technical aspects of the development and operation of gas-condensate properties.

Introduction

The recent discovery and development of gas reserves that contain hydrocarbons that condense with reduction of temperature or pressure, or both, to form a product known as condensate, has brought many new problems to the oil and gas industries. With further discovery of deep, high-pressure fields it is presumable that many more gas fields of this type will be added to the steadily increasing number. Such gas reserves are found either associated with oil as a gas cap or in separate formations. There seems to be no positive correlation between the physical or geological nature of the reservoir, and the chemical composition or phase characteristics of its contents.

Knowledge of the chemical make-up and phase behavior of gas-condensate reserves is needed to cope with many problems. A knowledge of the chemical composition and phase characteristics of the reservoir material is necessary to properly design a gasoline or recycling plant, to estimate natural gas and condensate reserves, to enable the operator to study the economic and technical aspects of various methods of operation and development, and to carry out the plan of operating subsurface and surface lease equipment. This information is often useful in questions of mineral ownership, proration, legal position, and taxation.

It is the purpose of this paper to discuss methods used by the writers to determine the chemical composition and phase characteristics of the fluids produced from a condensate well. The scope of the paper includes a discussion and description of the method of sampling, the results of tests on the accuracy of the sampling method, a description of a portable testing apparatus used to examine the phase characteristics, typical results of tests on wells from several condensate fields, and some of the applications of these data to production problems.

References to previous work on this subject are cited at the end of the paper.

The Problem

At reservoir conditions of temperature and pressure, the fluids produced from a condensate well exist in a homogeneous vaporous condition. The consequent reduction of temperature and pressure that occurs as this gas enters and flows up the well tube results in condensation of some of the hydrocarbon material to form a liquid. The relative amount of liquid condensed at any point in the flowing system

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* Union Producing Co., Shreveport, La.

† Consulting Engineer, Houston, Texas.

is a function of the pressure and temperature at that point.

In order to obtain an analysis of the reservoir material and determine its physical behavior at various temperatures and pressures, a representative sample must be obtained. Such a sample can be obtained, by means of a subsurface sampling device, at the bottom of the well, before any substantial reduction of temperature and pressure has occurred. If a sample is obtained elsewhere it must be taken so as to obtain aliquot parts of liquid and gas.

Of the many disadvantages to subsurface sampling of condensate wells one of the most significant is that in using ordinary sampling devices the size of the sample is insufficient to allow accurate determinations, with normal equipment, of the heavier hydrocarbon components. Therefore some other method of obtaining a sample of the well fluids is desirable, and it will be necessary that any such method procure proportionate parts of the liquid and gas phases.

Any ordinary oil and gas separator will serve as a sampling device. The entire stream of well fluids is passed through the separator where the liquid and gas phases are separated. By measuring the amount of each phase as a function of time and providing for the procurement of samples of each phase by conventional displacement methods, a representative sample of the well fluid can be synthesized. Fractional analysis of each phase can be made and an analysis of the reservoir material determined by combining these two analyses on a molar basis. To determine phase characteristics of the reservoir material the samples of liquid and gas can be recombined in proper proportions and treated in laboratory apparatus. This procedure involves elaborate equipment and has the further disadvantage that the size of sample that can be handled is so small that it is difficult to obtain accurate results. If means are provided at the well separator to maintain various separator temperatures and pressures, the phase relations of the reservoir material can be determined at the separator. To control the temperature and pressure of a separator in the field involves heavy equipment that is costly to install, operate and transport. Furthermore, separators are not always available, as in initially completed wells and wells producing to recycling plants. The apparent solution to the problem is to provide some means of securing representative samples of the reservoir material in some form of continuous process that will obtain only a small fraction of the total fluids flowing from the well, and thus allow treatment in a small portable testing apparatus.

Sampling the Well Stream

The highest pressure and temperature available as a sampling point is at the wellhead before the gas is subject to atmospheric cooling or throttling action. The least amount of liquid phase is present, therefore this is the ideal point at which to sample the well stream and obtain aliquot parts of liquid and gas. To take a sample at this point, a lubricator is installed in the top of the Christmas tree. As is shown in Fig. 1, the lubricator contains a piston which carries a tube. A streamlined tip is mounted on the lower end of the tube. Casing pressure and pump pressure are applied to the upper side of the piston, hydraulically forcing the piston to the bottom of the lubricator and therefore the sampling tube down into the Christmas tree, so that the streamlined tip is at a point in the well tubing where a sample may be taken from an undisturbed portion of the fluid flow. Pump pressure is provided by a small hand pump and conveyed to the top of the lubricator with standard drawn copper tubing. Fig. 2 shows the installation of the lubricator on a well being tested. After the lubricator is installed on the Christmas tree, the sample tube can be inserted within 5 min. and the operation is

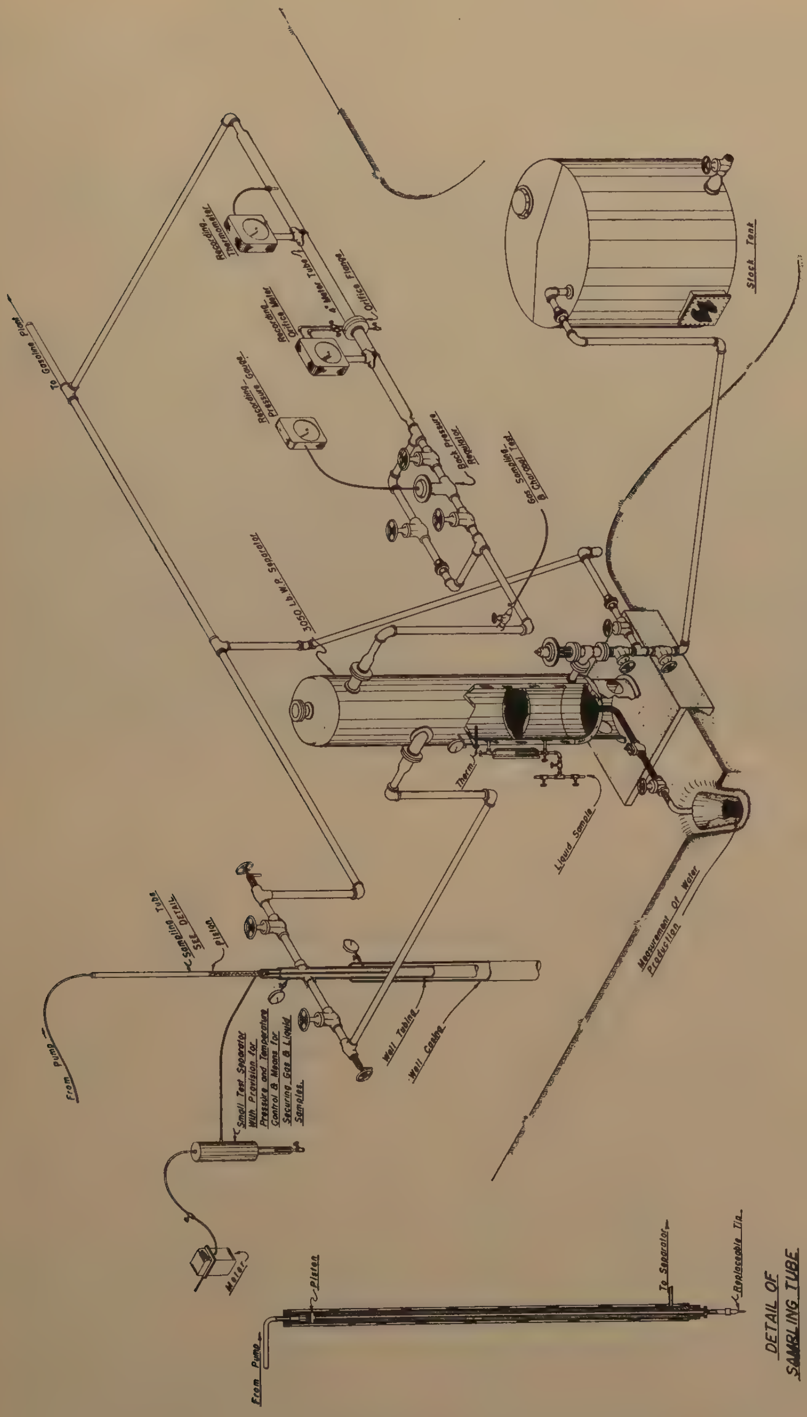

FIG. 1.—SAMPLING APPARATUS.

under control at all times. This method of sampling deserves some theoretical consideration. As the accuracy of the entire procedure is subject to the accuracy of sampling, this theory is the fundamental basis of the entire testing procedure.

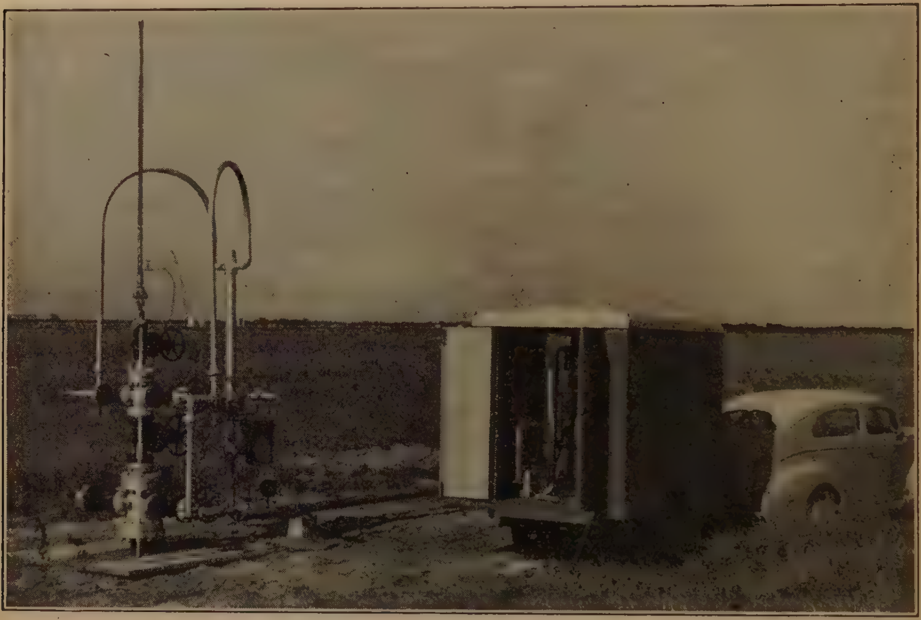

FIG. 2.—APPARATUS IN PLACE FOR TESTING.

Fig. 3 is an illustration of the sampling tip in the well tubing. The turbulent flow of gas is against the sampling tip. This gas contains a mist of liquid particles. Some liquid undoubtedly flows along the wet tubing wall but any appreciable amount, as it collects, is blown back into the turbulent stream by the velocity of gas in the tubing.

Knowing the cross-sectional area of the sampling tip *B*, the cross-sectional area of the well tubing *A*, and the total rate of fluid flow up the well tubing, the velocity at the point *b* can be made approximately equal to the velocity at the point *a* by controlling the rate of sampling. As the pressure and temperature at *a* and *b* are equal, identical velocities will be obtained at these points if the sampling rate is proportioned to the total fluid rate as the ratio of the cross-sectional area of *B* is to the cross-sectional area of *A*. Identical velocities are maintained during the sampling period.

A liquid particle approaching *a* is not disturbed from its path in motion by the presence of the sampling tip. Thus, if the liquid particles are uniformly distributed across the area of the well tubing a representative sample containing aliquot portions of liquid and gas will be obtained. Experiments have shown that if the velocity at *a* is greater than the velocity at *b*, an aliquot proportion of gas is not obtained. Also, if the velocity at *a* is less than the velocity at *b*, an aliquot proportion of liquid is not obtained. This can be explained by the fact that the liquid particles are slightly heavier than the gas and thus a greater velocity at *b* draws in more of the gas than liquid.

Two sets of test data are plotted in Fig. 8*C*, the only variable in each curve being the sampling rate, and the only variable between the two curves being the rate at which the well was produced. The ideal sampling rate is when ϕ is equal to unity. Theoretically the curves should cross when ϕ is equal to unity and the discrepancy shown in these curves represents an inconsistency in the sampling method. In this case the variation in results is about 1.5 per cent.

Fig. 8*D* shows the effect of two different sizes of sampling tip on the separator recovery. Again, the curves should cross when ϕ is equal to unity and the discrepancy shown in these curves represents an inconsistency in the sampling method. The variation in these results is about 3.1 per cent.

To sample or test a well it is necessary to have stabilized conditions of flow throughout the flowing system. The rate of flow must be great enough to keep all of the liquid particles moving upward uniformly in the tubing. There is no exact rule governing the rate above which flow must be maintained to keep all of the liquid particles moving upward uniformly in the tubing, but in general it may be stated that the higher the rate of flow, the more homogeneous the stream becomes. Also, wells that produce fluids rich in condensable material must be flowed at higher rates than wells producing fluids lean in condensable material. High-pressure wells must be flowed at rates greater than low-pressure wells. As a practical rule of thumb, the writers have found that stabilized flow can be maintained if linear velocities in the tubing are of the order of at least 15 to 20 ft. per sec. For testing purposes, the wells are generally produced at as high a rate of flow as is reasonable. High rates of flow tend to flatten the velocity-distribution curve shown in Fig. 3, and thus no appreciable error results from assuming this curve to be a horizontal straight line, as was done in the preceding discussion.

Tests on Accuracy of Method

To test the accuracy of the method, formations were chosen that varied in their content of liquid heavier than pentanes from about 600 gal. per million cubic feet to over 3000 gal. per million cubic feet. All of these producing formations were tested by the same procedure and equipment.

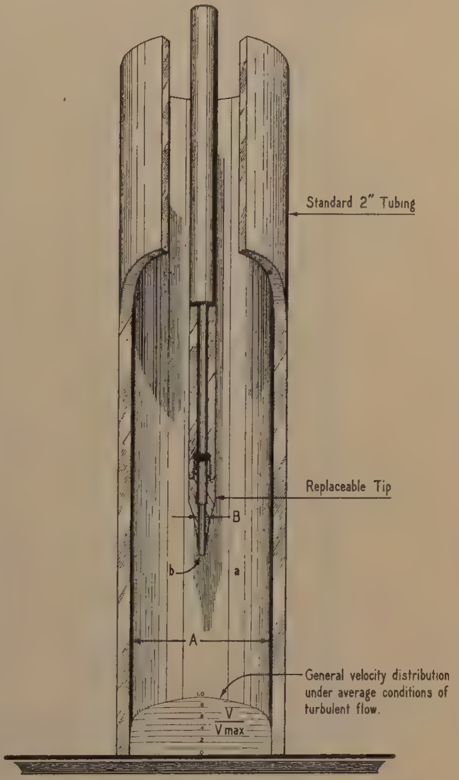
Standard 2" Tubing
Replaceable Tip
B
b
a
A
General velocity distribution under average conditions of turbulent flow.
1.0
.8
.6
.4
.2
0
$\frac{V}{V_{max}}$

Fig. 3.—Sampling tip in well tubing.

A diagram of the equipment is shown in Fig. 1. It consisted essentially of two parts, equipment for taking a complete set of observations and samples from a 30-in. by 11-ft. separator, and equipment to take observations and samples simultaneously from the portable testing apparatus, which was fed from the sampling tube in the well tubing. All equipment had a working pressure greater than 3000 lb. per sq. inch. The portable testing apparatus was maintained at the same temperature and pressure as the large separator, and observations and samples were taken at both.

Tables 1 and 2 summarize the results of these tests. The various tests are indicated

TABLE 1.—*Comparison in Results of Tests with Standard Separator and Portable Separator*

Test No.	Separator Conditions		Rate of Separator Condensate Yield, Bbl. per Million Cu. Ft. Gas		Difference, Per Cent	A.S.T.M. Charcoal Tests of Separator Gas, Bbl. per Million Cu. Ft. Gas		Difference, Per Cent	Difference Composite Analyses, Per Cent
	Pressure, Lb. per Sq. In. Gauge	Temperature, Deg. F.	1[a]	2[b]		1[a]	2[b]		
A	1,505	103	7.8	8.3	+6.4	11.01	10.33	−6.2	+1.9
B	1,191	93	11.3	11.5	+1.8	8.49	8.98	+5.8	−1.8
C	892	81	13.6	13.6	0.0	7.19	7.79	+8.3	+0.50
D	595	64	14.8	14.6	−1.4	6.15	6.15	0.0	+0.47
E	1,500	98	15.1	14.3	−5.3	12.21	12.95	+6.1	−2.8
F	1,200	89	18.0	17.4	−3.3	9.09	9.08	−0.11	−2.4
G	900	76	21.1	20.1	−4.7	7.78	7.95	+2.2	[c]
H	600	64	21.5	20.8	−3.3	6.43	6.58	+2.3	[c]
I	1,495	85	108.3	97.1	−10	10.02	10.66	+6.4	+2.5
J	1,200	77	106.6	97.1	−8.9	8.29	8.58	+3.5	[c]
K	900	69	97.2	92.5	−4.8	5.81	5.68	−2.2	−4.5
L	600	57	93.7	84.4	−9.9	4.49	4.49	0.00	−5.2

[a] Standard separator. [b] Portable testing apparatus. [c] Samples lost.

TABLE 2.—*Comparison in Calculated Reservoir Analyses*

MOL PER CENT[a]

	A				B				C			
	1		2		1		2		1		2	
		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.
C_1	91.60		91.50		91.37		91.39		91.18		91.20	
C_2	4.52		4.44		4.54		4.54		4.56		4.56	
C_3	1.61		1.71		1.60		1.60		1.66		1.65	
iC_4	0.53	0.172	0.55	0.178	0.56	0.182	0.61	0.198	0.57	0.185	0.58	0.188
NC_4	0.47	0.147	0.49	0.153	0.52	0.163	0.47	0.147	0.55	0.172	0.56	0.175
C_5	0.45	0.163	0.52	0.188	0.51	0.184	0.50	0.181	0.52	0.188	0.50	0.181
C_6	0.34	0.138	0.36	0.146	0.33	0.134	0.36	0.146	0.47	0.191	0.38	0.154
C_7+	0.48	0.268	0.43	0.240	0.57	0.315	0.53	0.288	0.49	0.267	0.57	0.310
Total	100.00	0.888	100.00	0.905	100.00	0.978	100.00	0.960	100.00	1.003	100.00	1.008

	D				E				F			
	1		2		1		2		1		2	
		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.
C_1	91.20		91.14		90.78		90.76		90.53		90.56	
C_2	4.52		4.53		4.37		4.41		4.40		4.37	
C_3	1.64		1.74		1.76		1.82		1.73		1.83	
iC_4	0.59	0.191	0.61	0.198	0.71	0.230	0.77	0.250	0.72	0.234	0.68	0.221
NC_4	0.49	0.154	0.49	0.154	0.52	0.163	0.51	0.160	0.55	0.172	0.52	0.163
C_5	0.55	0.199	0.52	0.188	0.64	0.231	0.65	0.235	0.80	0.289	0.76	0.275
C_6	0.37	0.150	0.41	0.166	0.51	0.207	0.40	0.162	0.47	0.191	0.47	0.191
C_7+	0.64	0.372	0.63	0.365	0.71	0.371	0.68	0.361	0.80	0.409	0.81	0.414
Total	100.00	1.066	100.07	1.071	100.00	1.202	100.00	1.168	100.00	1.295	100.00	1.264

	I				K				L			
	1		2		1		2		1		2	
		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.		Gal. per M Cu. Ft.
C_1	83.79		83.88		84.41		84.64		84.15		84.67	
C_2	4.96		4.89		4.59		4.65		4.57		4.55	
C_3	3.32		3.20		3.12		3.12		3.12		3.02	
iC_4	1.32	0.428	1.53	0.496	1.34	0.435	1.55	0.503	1.49	0.483	1.49	0.483
NC_4	1.46	0.457	1.25	0.392	1.47	0.461	1.27	0.398	1.19	0.373	1.09	0.342
C_5	1.36	0.492	1.38	0.499	1.43	0.517	1.39	0.503	1.43	0.517	1.35	0.488
C_6	1.27	0.515	1.11	0.451	0.86	0.349	0.82	0.333	0.96	0.390	0.96	0.390
C_7+	2.52	1.436	2.76	1.574	2.78	1.600	2.56	1.474	3.09	1.758	2.87	1.635
Total	100.00	3.328	100.00	3.412	100.00	3.362	100.00	3.211	100.00	3.521	100.00	3.338

[a] Alphabetical letters correspond to test numbers shown in Table 1.

by alphabetical letters. The results obtained from the standard separator are shown in column 1 and the results obtained with the portable testing apparatus in column 2. The accuracy of the sampling method is demonstrated by comparing columns 1 and 2.

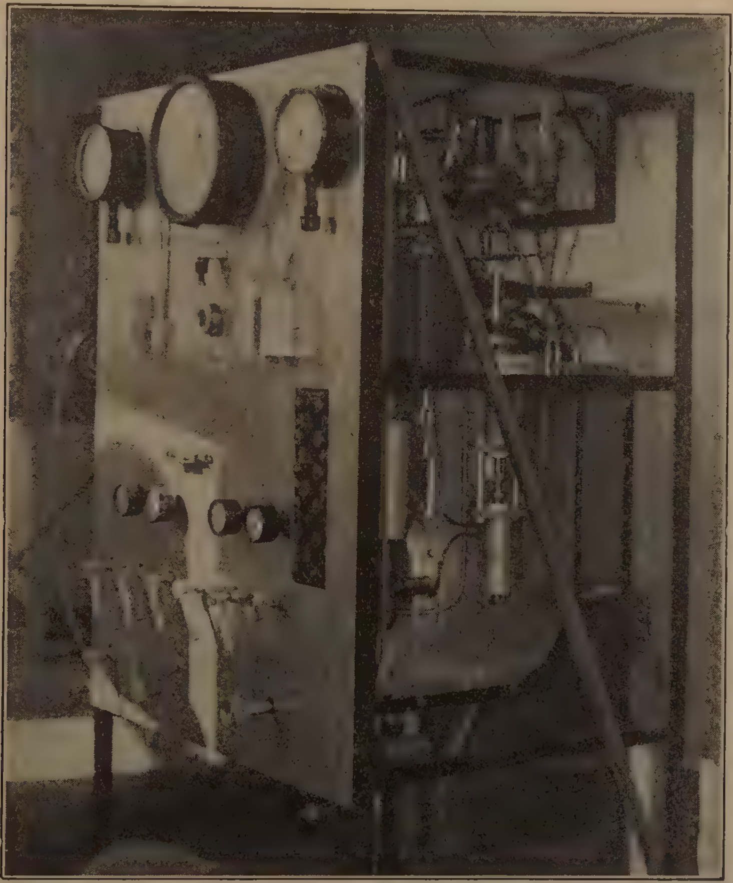

FIG. 4.—ESSENTIAL PARTS OF APPARATUS.

Table 1 shows a comparison between the two methods in the ratios of separator liquid condensate to volume of gas, and the percentage deviation of the results obtained with the standard separator to that of the portable testing apparatus. A comparison is also shown of the gasoline content of the separator gas as determined by A.S.T.M. charcoal tests. The last column is the percentage deviation of the content of hydrocarbons heavier than propane as computed from the composite analysis in Table 2. All gas volumes are computed at 60°F. and 14.65 lb. per sq. in. absolute.

Table 1 shows that deviations as great as 10 per cent occur in some of the tests of condensate yield, but these deviations are considerably reduced on the basis of the composite analyses. The writers believed this to be due partly to the small size of the separator in the portable testing apparatus when handling large amounts of liquid, therefore it was increased in size as a result of these tests. The deviation between the two methods increases with gas rich in condensable components, because a larger percentage of liquid is present at the sampling point and this decreases the accuracy of sampling. The probable variation in sampling the well stream to determine the content of hydrocarbons heavier than propane was calculated from tests to be approximately 1 per cent. Since these comparative data were taken, a recycling plant has been built and has been operating for 18 months in the field in which the data were taken. Periodic tests have been made with the sampling tube and portable testing apparatus, to determine for each well the content of hydrocarbons that would be recovered by the conventional absorption process at the recycling plant. Knowing the volumes of gas produced from each well and the content from these tests, a theoretical plant yield was calculated. Over a period of 18 months operation, this theoretical plant yield has had a maximum deviation of about 7 per cent, and an average deviation of less than 1 per cent from the actual plant yield. These operating data are the best proof of the accuracy of the sampling device.

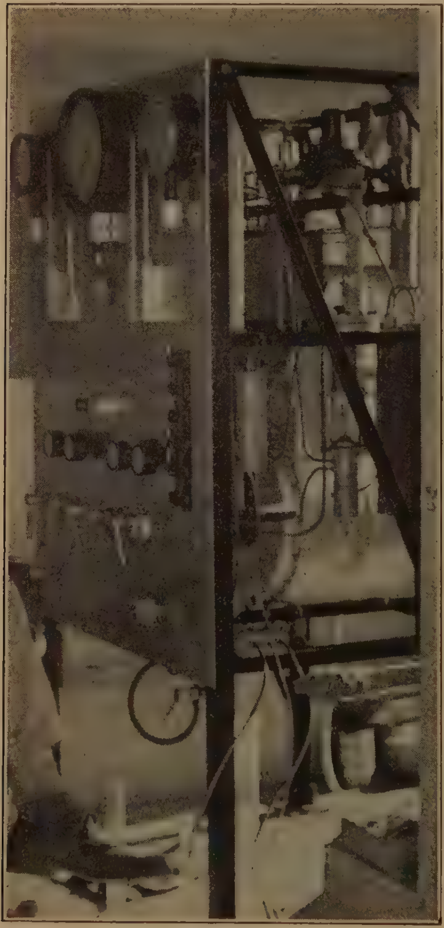

FIG. 5.—ESSENTIAL PARTS OF APPARATUS.

PORTABLE TESTING APPARATUS

The portable testing apparatus is mounted in a trailer (Fig. 2). Two views of the essential parts of the apparatus are shown in Figs. 4 and 5. The equipment consists of a small separator machined from solid steel stock. Mounted on the bottom of the separator is a calibrated liquid accumulator. Heat exchangers are provided, so that the fluid may be brought to the desired temperature before entering the separator. Cooling is done by exchanging a diverted part of the fluid stream through an exchanger that uses throttled gas from the well casing as a cooling medium. The cooled, diverted stream is recombined and allowed to become thoroughly mixed before it enters the separator and the amount of diverted gas is automatically controlled to maintain a constant separator temperature during a test. Heating is done in a similar manner, using hot circulated glycerin as a heating medium.

After being reduced to approximately atmospheric pressure by a back-pressure regulator, the volume of separator gas is measured by a positive-displacement type of gas meter.

Heat is supplied to all control valves and lines subject to freezing from the formation of gas hydrates. The sizes of all lines and

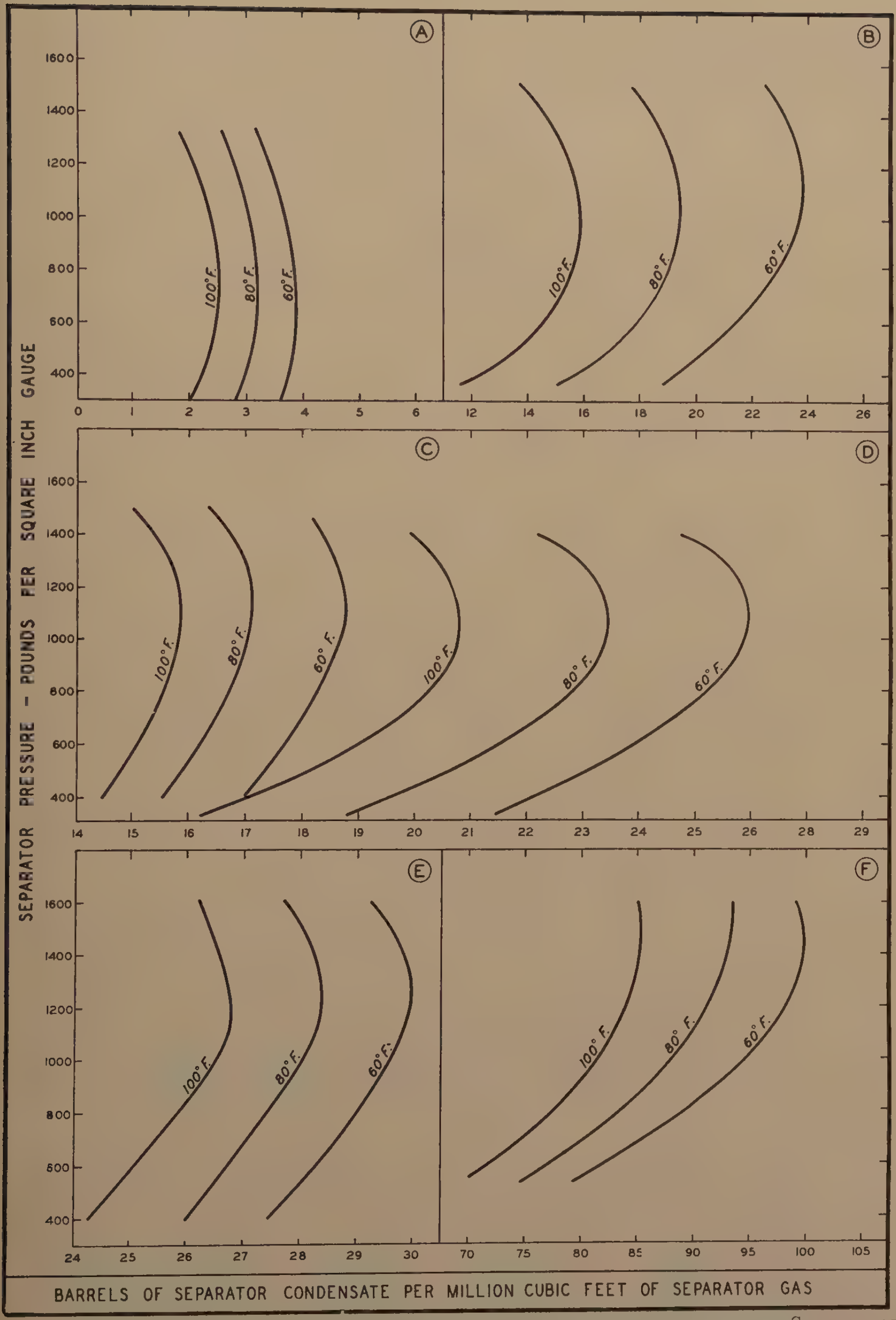

Fig. 6.—Effect of separator pressure and Temperature on condensate yield. Six typical Gulf Coast fields.

connections are kept at a minimum to prevent slugging of any liquid condensed before entering the separator.

Mounted in the trailer is a hand pump, which is used to force into the well tubing the piston carrying the sample tube. A small compressor is provided so that the fluid entering the apparatus may be increased to as great as 10,000 lb. per sq. in. before it enters the heat exchangers and separator.

Means are provided to secure samples of separator gas and liquid for analyses or further tests, and to conduct stage-separation tests.

After the sample tube has been lowered in the well tubing, the rate of fluid flow through the apparatus is adjusted to the proper rate. The test data are then obtained, and it is not necessary to remove the sampling tube or leave the trailer between tests.

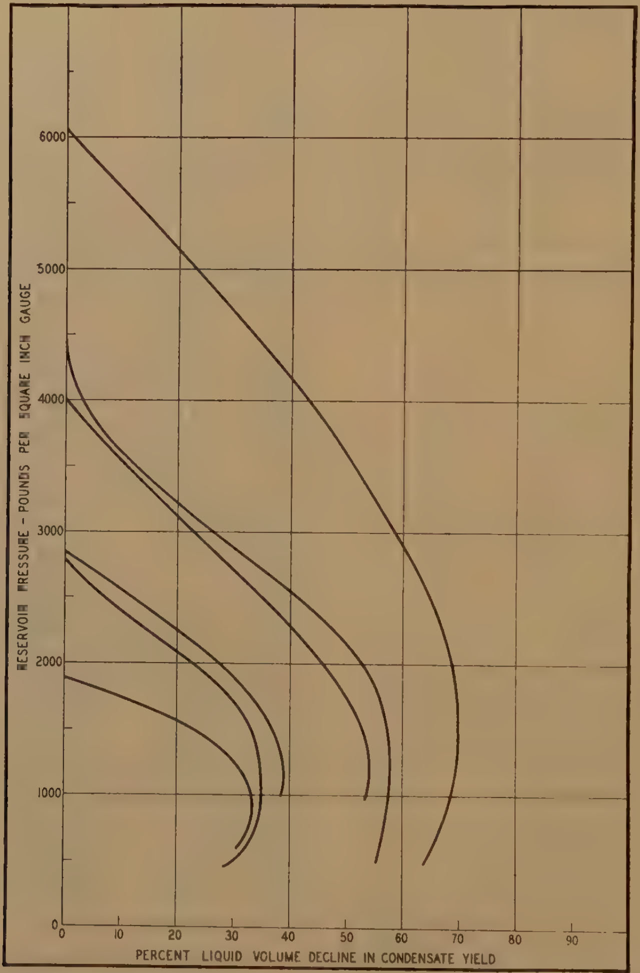

FIG. 7.—RETROGRADE CONDENSATION AT RESERVOIR TEMPERATURE. SIX TYPICAL GULF COAST FIELDS. SEPARATOR CONDENSATE YIELD AT 1200 LB. PER SQ. IN. AND 70°F. EQUALS 100 PER CENT.

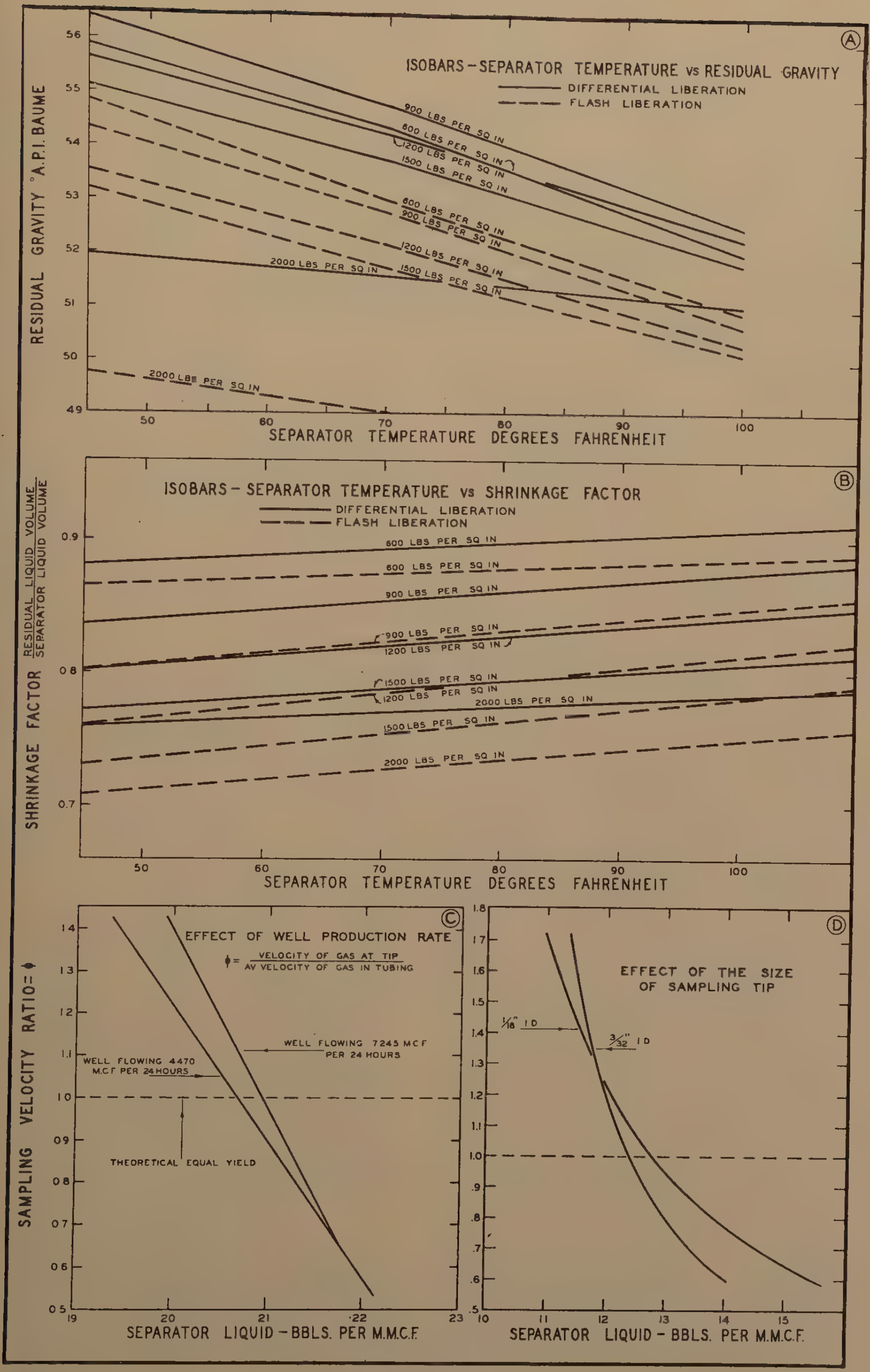

FIG. 8.—TEST DATA.

TYPICAL RESULTS AND APPLICATIONS

Typical data obtained with the portable testing apparatus in fields in the Gulf Coast area are plotted in Figs. 6, 7 and 8.

The data shown in Fig. 6 are useful in studying the optimum operating conditions of surface lease equipment. These data, together with those in Figs. 8*A* and 8*B*, can be used to study the economics of stage separation. When samples of the gas and liquid phases are taken from the portable testing apparatus and analyzed by fractionation; the two analyses can be recombined to yield an analysis of the reservoir material from which the reserve of condensate in place can be ascertained. The molar ratio by which the analyses are combined is obtained from such data as are plotted in Fig. 6.

Where gas produced from a field is treated in a gasoline plant, it is economical and efficient to do away with separators and tanks on individual leases and thus eliminate the loss in flashing and weathering the condensate in tank batteries throughout the field. The problem of allocation of royalties between leases arises with the elimination of individual condensate measurement on each lease. Periodic tests can be made with the portable apparatus to determine the content of condensate in the gas, and the amount to be allocated to each lease is calculated from these data. In one South Texas field, the condensate recovered by a recycling plant is allocated on the basis of such tests between leases and between producing formations.

In studying the economics of recycling operations or in estimating recoverable condensate reserves, the data plotted in Fig. 7 are used to predict the loss of condensate in the reservoir resulting from pressure reduction. For convenience here, percentage loss is plotted for the abscissa instead of the volume ratio of condensate to gas. The plots are differential functions, hence the value of the abscissa at any pressure is an instantaneous value. To obtain the volume of condensate loss in a reservoir, it is necessary to integrate such curves between pressure limits. Since volumetric reservoir data are usually available, the pressure decline as a function of cumulative withdrawal can be estimated and used together with such a curve to estimate loss in the reservoir resulting from pressure decline. The reservoir "dew point" is shown at the point where the curves intersect the ordinate.

CONCLUSIONS

The sampling-tube method of sampling gas-condensate wells, when properly employed, will obtain a representative sample of the well fluid consisting of aliquot parts of liquid and gas. The method is sufficiently accurate for all practical and engineering purposes.

A method is now being developed to obtain a representative sample of a fluid existing in two phases while flowing through a horizontal pipe. Sufficient data are not yet available to warrant a detailed discussion, but it can be said that experiments thus far conducted indicate results similar to those obtained with the vertical sampling tube.

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DISCUSSION

(*T. V. Moore presiding*)

D. L. KATZ,* Ann Arbor, Mich.—Flaitz and Parks present excellent data on the comparison of well effluents sampled by conventional separators on the entire well stream with effluents sampled by taking a portion of the flowing stream. The conclusions of their tests appear to be that the new method has a good chance of giving the analyses for the well effluent within the accuracy of conventional methods but may err as much as 10 per cent on occasion. For general engineering work, the proposed method has many advantages but does not supplant the conventional field separators on the entire well stream as the most reliable procedure.

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* Assistant Professor, Department of Chemical and Metallurgical Engineering, University of Michigan.

The problem resolves itself down to the liquid-phase distribution in the flowing gas stream at the sampling point. If the two-phase system approaches a uniform dispersion of liquid in vapor, the sampling tube may remove an aliquot portion of vapor and liquid phases. As mentioned in the paper, the degree of mixing of the two phases depends upon the turbulence or velocity of flow.

An added refinement to the proposed method may be the calculation of the Reynolds number or other criteria to evaluate the degree of turbulence for the flowing stream just ahead of the sampling tube. Possibly the percentage error between the conventional and proposed methods would be related to this degree of turbulence and the percentage of liquid phase present. If increasing the velocity assists in mixing the two phases, would it be worth while to consider placing a joint of extra heavy tubing at the top of the string in condensate wells to give a smaller cross section of flow for sampling operations?

I believe the literature on the flow of heterogeneous phases would be fundamental to any further study of the problem.

J. S. SWEARINGEN,* Austin, Texas.—In sampling by inserting a tube into a gas stream containing a suspended liquid phase, the question always arises as to how much of the liquid is suspended, and therefore accessible to the sampling tip, and how much is moving along on the wall of the pipe, and therefore not included in the gas sample.

The sampling method described relies on the lack of turbulence within the straight path up the tubing and on absence of turns as assurance that little of the suspended liquid will be thrown out and deposited on the walls, and thus evade sampling.

The authors presented the data in Table 1 exactly as it was recorded, but they regard as inaccurate the percentage difference between test separator and standard separator yields in tests I, J, and L for the case of very rich wells, because of errors in gas measurement, and they consider a value of minus 5.0 to be more consistent with many data that have been recorded but not reported because of limited space. Accordingly, this consistent value of minus 5 per cent represents the results obtainable for a rich well, the portable apparatus giving results that are 5 per cent low.

At the point at which the sample was taken about 50 per cent of the recoverable product was still in the gas phase. An error of 5 per cent in quantity of liquid recovered owing to an error in sampling would, therefore, be caused by an error of approximately 10 per cent in sampling the liquid phase, since only half the recovered liquid was in the liquid phase at that point. That is to say, under the conditions at which the results were recorded only 90 per cent of the aliquot part of the liquid phase was collected by the sampler.

But the conditions of sampling were these: The sampling tip was placed near the center of the stream, where the velocity of the stream was greater than the average velocity, whereas the sampling rate, or flow into the sampling tip, was at the average stream velocity. This maximum velocity, shown qualitatively in the lower part of Fig. 3, is about 14 per cent greater than the average velocity. According to the curves in Figs. 8*C* and 8*D*, this erroneous sampling would cause the sample to be 2.5 per cent too rich because too much of the liquid phase was collected; and if only half the recoverable liquid was in the liquid phase at the point of sampling, the indication would be that the sample was 5 per cent too rich in the liquid phase that was present. The inference is that sampling at the proper rate would collect about 85 per cent of the aliquot part of the liquid phase.

Hence, by sampling inside the tubing where little turbulence has been encountered to remove the liquid from its suspended state in the gas, and where pressure and temperature are at a maximum, the error in the sampling method appears to be only a few per cent in very rich wells and still smaller in wells that are not so rich. By sampling at the average rate of flow, which is somewhat slower than the prevailing velocity at the point of sampling, some additional liquid is collected, and this, according to the data, brings the results for the portable apparatus practically into agreement with results from the standard separator.

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* Professor of Chemical Engineering, University of Texas.

A. L. Vitter, Jr.,* Baton Rouge, La.—Although the sampling-tube method has been used extensively, there has not been much, if any, published material of a quantitative nature to establish its reliability. As pointed out by the authors, some small errors are incurred in this method, but not sufficient to prohibit its use for general engineering and routine test work, for which it is particularly used and adapted.

Fig. 7, which is obtained experimentally by the equipment described at *one* point in the life of the reservoir, is not applicable, without modification, to calculate the condensate loss in the reservoir at any particular time in the life of the reservoir, as is stated near the end of the paper. This cannot be done because the macroscopic condensation characteristic of the reservoir fluid, as shown in Fig. 7, applies only to the reservoir fluid at that time. As the reservoir pressure declines, liquid condenses out and the gas phase is produced from the well bores; and this gas phase is a system different from the virgin system or the gas phase of the reservoir fluid at any previous moment in the life of the reservoir. Therefore it will have different condensation characteristics.

K. Eilerts,† Bartlesville, Okla.—The authors mention a small compressor for increasing the pressure on the fluid entering the heat exchangers and separator to as much as 10,000 lb. per sq. in. What type of pump was used, and how was it operated to obtain the desired separator pressures?

J. M. Flaitz (author's reply).—Mr. Parks and I agree with Dr. Katz's comments and his suggestion as to more fundamental research in this method of sampling.

Dr. Swearingen has given a good analysis of compensating errors in the velocity sampling method. The two sources of errors in this method are the lack of even distribution of liquid particles and the velocity of sampling. Distribution of liquid particles is directly affected by the quantity of liquid carried along the conductor wall, and must be related to velocity and turbulence. In a nonwetting mixture, such as dust-laden gases investigated by Brady and Touzalin,[6] the problem of uneven particle distribution was not encountered and these investigators showed that a representative sample of gas and dust particles was obtained when the velocity of sampling was identical with the velocity of fluid flow at the sampling point.

Mr. Vitter's comment regarding the data plotted in Fig. 7 is technically correct. However, the method described for determining the loss in a reservoir of condensate by retrograde condensation resulting from reduction in reservoir pressure is sufficiently accurate for engineering calculations, and is the best approach to the problem.

Table 3.—*Comparison of Flash and Differential Condensation*

Calculated Reservoir Condensation at 211°F. Barrels of Condensate per Million Cubic Feet of Reservoir Gas

Pressure, Lb. per Sq. In.	Flash Condensate			Differential Condensate
	A	B	C	D
4,587	0	0	0	0
4,250	1.3			2.02
4,000	2.7	0.82	2.5	3.66
3,500	7.6	2.9	6.5	6.95
3,000	12.3	5.1	9.8	9.35
2,500	17.0	7.5	12.7	11.24
2,000	21.0	9.6	13.6	12.57
1,500	24.0	11.5	15.6	12.89
1,000	24.8	13.7	16.1	12.57
500	23.5	14.8	15.7	11.87
0		15.6	15.6	11.05

Condensation can occur in the reservoir by two methods—flash condensation and differential condensation. In flash condensation the liquid phase condensed is always in contact with the vapor phase, whereas in differential condensation the vapor phase is removed and separated from the liquid phase as the gas phase is produced. A comparison between these two phenomena on reservoir samples from a gas-condensate field are shown in Table 3.

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† Physical Chemist, U. S. Bureau of Mines.

[6] Brady and Touzalin: *Jnl. Ind. and Eng. Chem.* (Sept. 1911).

Flash condensate was determined and calculated in the following manner. A sample was taken as described in the paper and passed through the test separator, which was maintained at reservoir temperature. The amount of condensate recovery per unit volume of gas was determined at various pressures (column A, Table 3). These data were plotted and the curve integrated to give the data in column B. The loss that would occur in the reservoir is shown in column C; it was determined from columns A and B as illustrated by the following example for the loss at 3500 lb. per sq. in.; 23.6 per cent would be produced with a loss of 2.9 bbl. per MM cu. ft. and 76.4 per cent would remain in the reservoir with a loss of 7.6 bbl. per MM cu. ft., giving an average loss of 6.5 bbl. per MM cu. feet.

Differential condensate shown in column D was determined in the laboratory on a synthetic reservoir sample. The bomb[7] was maintained at reservoir temperature and gas was slowly withdrawn from the top of the bomb. The contents of the bomb were agitated. Gas was withdrawn in increments to give the pressures shown in the table, and for each increment the amount of condensate was measured.

The writer believes that in actual practice a combination of flash and differential condensation occurs, so that the actual reservoir loss would be between the limits shown in columns C and D. The chemical composition of any barrel of condensate is not considered by these methods.

A. S. Parks (author's reply).—Answering Mr. Eilerts' question: The pump is a small packed plunger, single-acting type, driven by a 3-hp. gasoline engine. The piston has a ⅜-in. diameter and a 2-in. stroke. In operation, the pump runs at a constant rate and the discharge pressure is controlled by throttling the compressor suction.

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[7] Described by W. F. Fulton: Amer. Petr. Inst. Drill. and Prod. Practice (1939) 354.

Possibilities of Secondary Recovery for the Oklahoma City Wilcox Sand

By Donald L. Katz,* Member A.I.M.E.

(Dallas Meeting, October 1941)

The Oklahoma City Wilcox sand, discovered on March 26, 1930, has produced 394 million barrels of crude oil and 819 billion cubic feet of natural gas as of July 1, 1941. The 100,000-bbl. wells, pressures of 2600 lb. per sq. in., and flows of "Wilcox" sand caused exciting moments in the early life of the field. Today the reservoir is substantially at atmospheric pressure and produces 75,000 bbl. of crude oil daily through 466 pumping wells. Early estimates of the initial crude-oil content of the "Wilcox" sand[1] indicated that about 600 million barrels of crude oil would remain after the pumping wells ceased to produce economically. The Oklahoma City Wilcox Secondary Recovery Association was organized in March 1939, to study the possibilities of recovering a portion of this oil.

Only a very brief summary of the information available can be presented in a paper of this nature. Some simplifications and generalizations are necessary to give the over-all picture in so short a space and statements made may not apply to a specific well or small area. Since the area under consideration by the Association is that north of the south line of section 22-11-3, some information will be presented for areas A, B, C, 1, 2, 3 and part of 4 of Fig. 2, and some will be for the entire Wilcox zone west of the fault.

This paper is essentially an abstract of an engineering report made by A. D. Small, B. T. Murphree, M. C. Sons and the author for the Oklahoma City Wilcox Secondary Recovery Association on Sept. 5, 1940. Some information is taken from a report to the Association by C. V. Sidwell on March 1, 1940, and some data are from a recent report by A. D. Small. It gives a brief history of the Wilcox zone, estimates of the initial oil contents of the reservoir, present conditions in the reservoir, and probable results from several programs of "secondary recovery."

History of Wilcox Zone

The Wilcox sand lies on the flank of the general structure, as shown by cross section of Fig. 1[2,3,4] and areal map of Fig. 2. The sand is of Ordovician age and is composed of well assorted, rounded sand grains with no apparent cementing material. The loose texture of the sand is shown by the enormous quantities of sand production from the wells and from the soft cores. The productive sand varies from zero thickness on the east to 220 ft. maximum and to zero thickness on the west because of water.

The development of the pool[4] was dependent upon drilling restrictions within the city limits, which accounts for the spacing of drilling operations listed in Table 1 by years. In 1931, areas 1 through 7 of Fig. 2 were open for drilling with the exception of some west-edge properties, and all wells drilled before Feb. 1, 1935, were in this portion of the field. Nearly all wells drilled from 1933 to 1937 were in areas A, B and C. Since 1939, the newly drilled wells have gradually enlarged the producing area toward the west in the northern portion.

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[1] References are at the end of the paper.

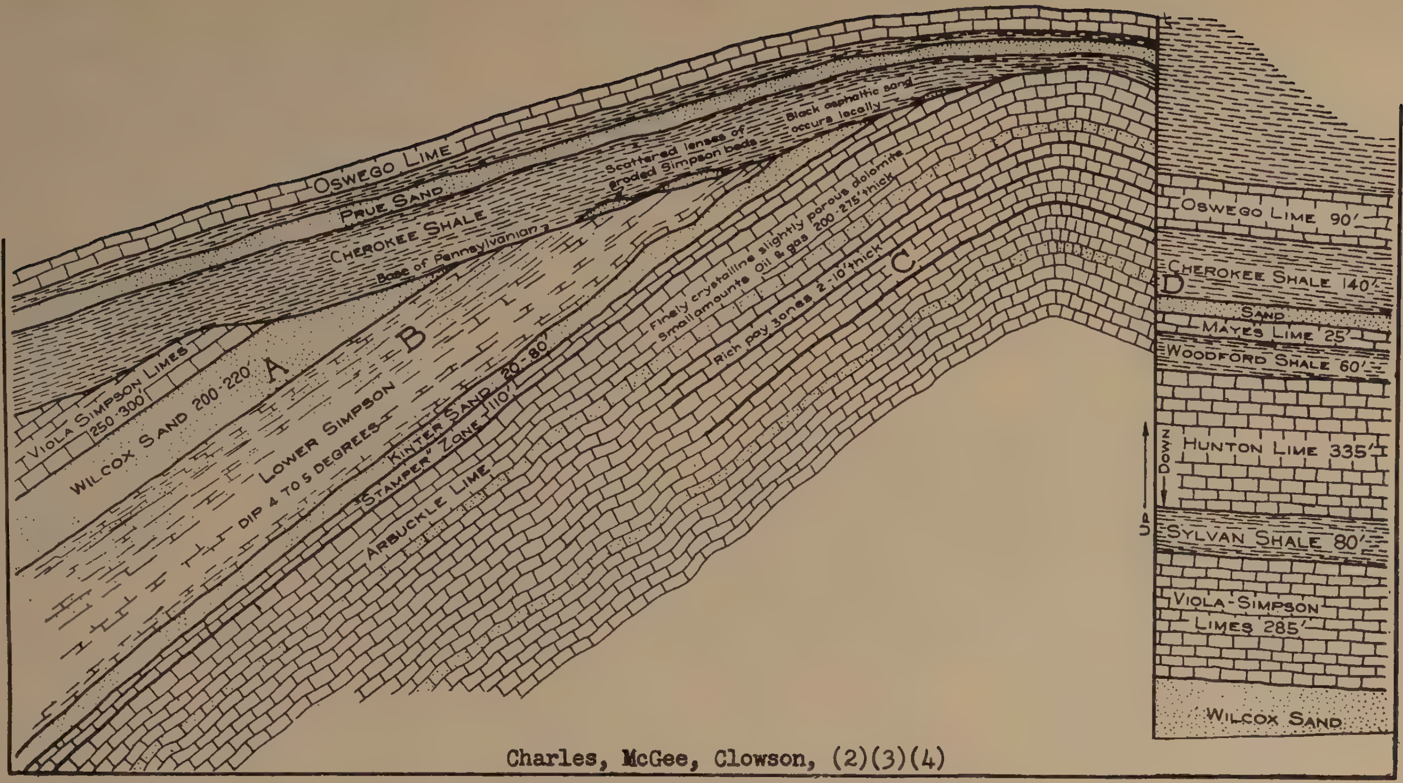

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Fig. 1.—Generalized cross section of Oklahoma City field.

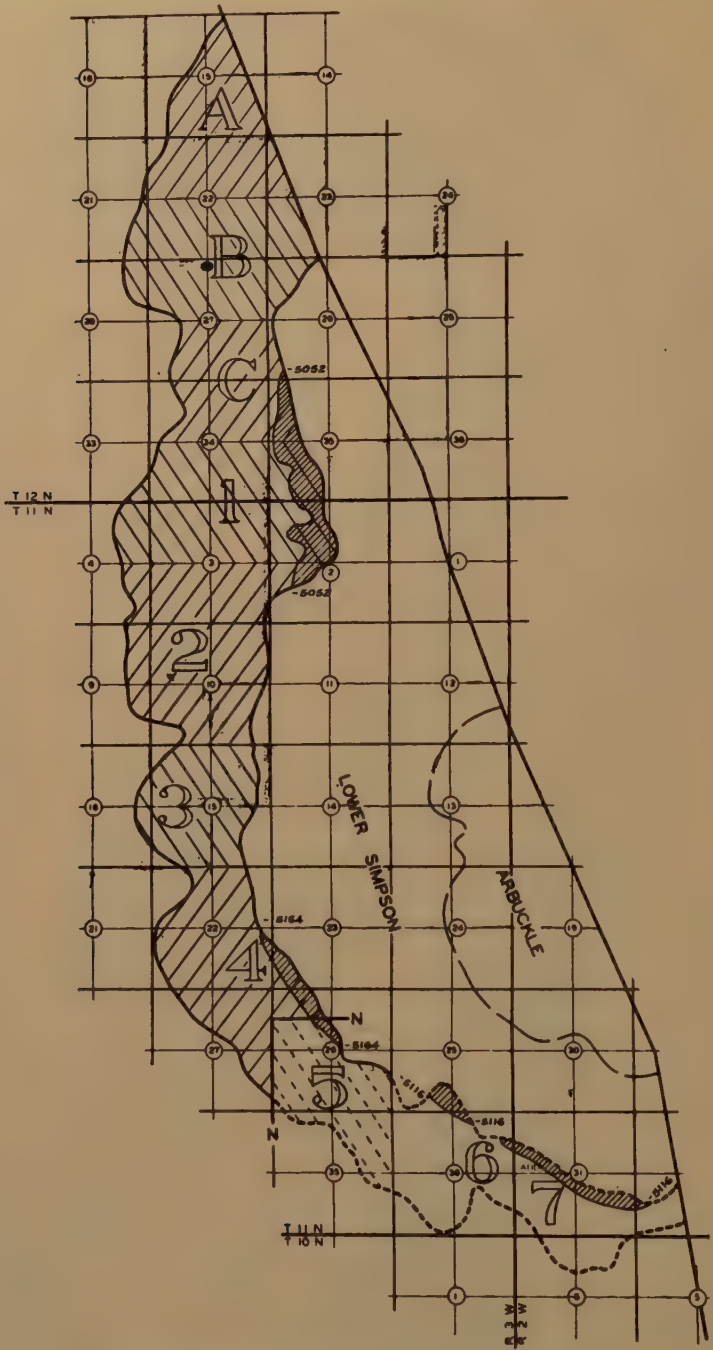

Fig. 2.—Areal map showing initial Wilcox gas cap.

TABLE 1.—*Production Record, Oklahoma City Wilcox Sand*[a]

End Year	Accumulative Oil Production, Million Bbl. Pipe-line Oil	Accumulative Gas Production, Billion Cu. Ft. 14.65 Lb. 60°F.	Total Number Wells Drilled
1930	6.2	6.3	150
1931	38.2		315
1932	67.0	177	452
1933	114.2	378	504
1934	159.3	550	567
1935	203.2	630	608
1936	244.7	701	767
1937	289.7	751	807
1938	320.1	780	809
1939	349.6	797	811
1940	380.0	812	827
1941 (July 1)	394.0	819	842

[a] As of July 1, 1941 the record was 466 producing wells, 114 shut down or gas input, 48 plugged back, abandoned and 15 drilling.

TABLE 2.—*Typical Analyses*

Constituent	Calculated Initial Reservoir Liquid	Separator Gas in 1933, Mol Fractions	Casinghead Gas in 1940
Oxygen and nitrogen	—		0.0719
Methane	0.3778	0.839	0.5850
Ethane	0.0871	0.097	0.1268
Propane	0.0628	0.039	0.1021
Butanes	0.0435	0.170	0.0643
Pentanes	0.0328	0.008	0.0264
Hexanes	0.0367		0.0150
Heptanes and heavier	0.3593		0.0085
Saturation temperature, deg F	132	67	
Saturation pressure, lb. per sq. in. abs.	2,660	95	

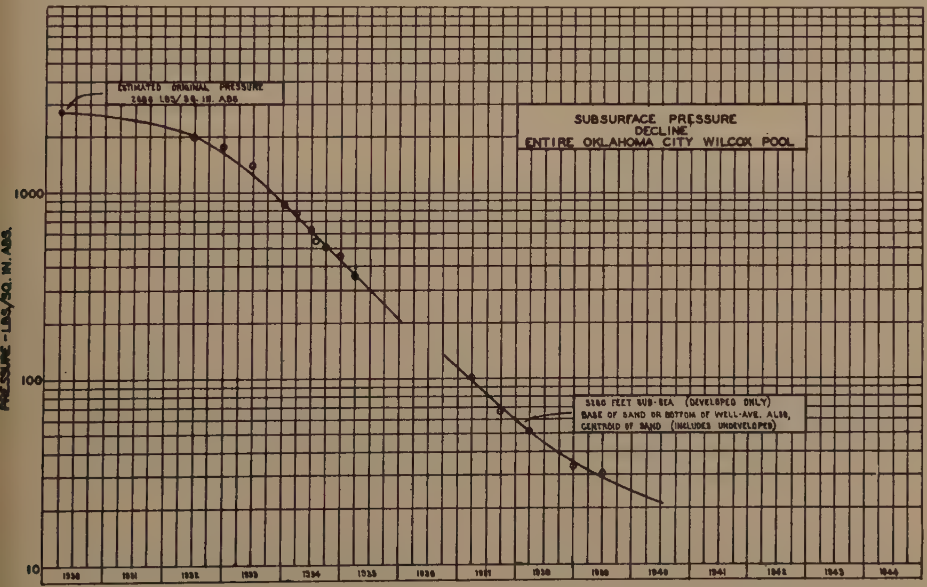

FIG. 3.—AVERAGE PRESSURE OF DEVELOPED RESERVOIR AT 5260 FEET SUBSEA.

The first known reservoir-pressure measurement was made by Mr. Pat McDonald on Dec. 6, 1931, with regular surveys beginning in June 1932 to give the values of Fig. 3. The productions of crude oil and natural gas are tabulated in Table 1. The crude-oil figures include estimates of "hot" oil and the natural-gas quantities include estimates of "popped" gas that was not processed for natural gasoline. The initial reservoir-liquid analysis, as estimated from Lindsly's bottom-hole samples taken in 1933[4,5] is given in Table 2 along with typical gas analyses. The pipe-line crude oil has been in the 38° to 39° A.P.I. bracket for the most part.

Proration has existed over the entire life of the pool, allowables varying from less than 1 per cent in the flush period to 95 per cent at the present time. Minimum well allowables have varied from 50 to 300 bbl. per day.

The end of the natural flow period occurred in 1934 on the average for the early drilled portion; gas lift followed for about one year, then pumping began. Wells in the newly drilled portion of the field in 1935 and 1936 flowed for some time with reservoir pressures at 6500 ft. of 200 lb. or less. At the present time, all wells are on the pump, 355 on the beam, 79 Kobe hydraulically operated installations and 32 electrical Reda pumps. As of July 1, 1941, 30 wells were reported capable of producing between 500 and 1000 bbl. per day. The average production is 159 bbl. per day per well with a gas-oil ratio of 500 cu. ft. gas per barrel of oil. Fig. 4 shows monthly oil and gas production data for recent years.

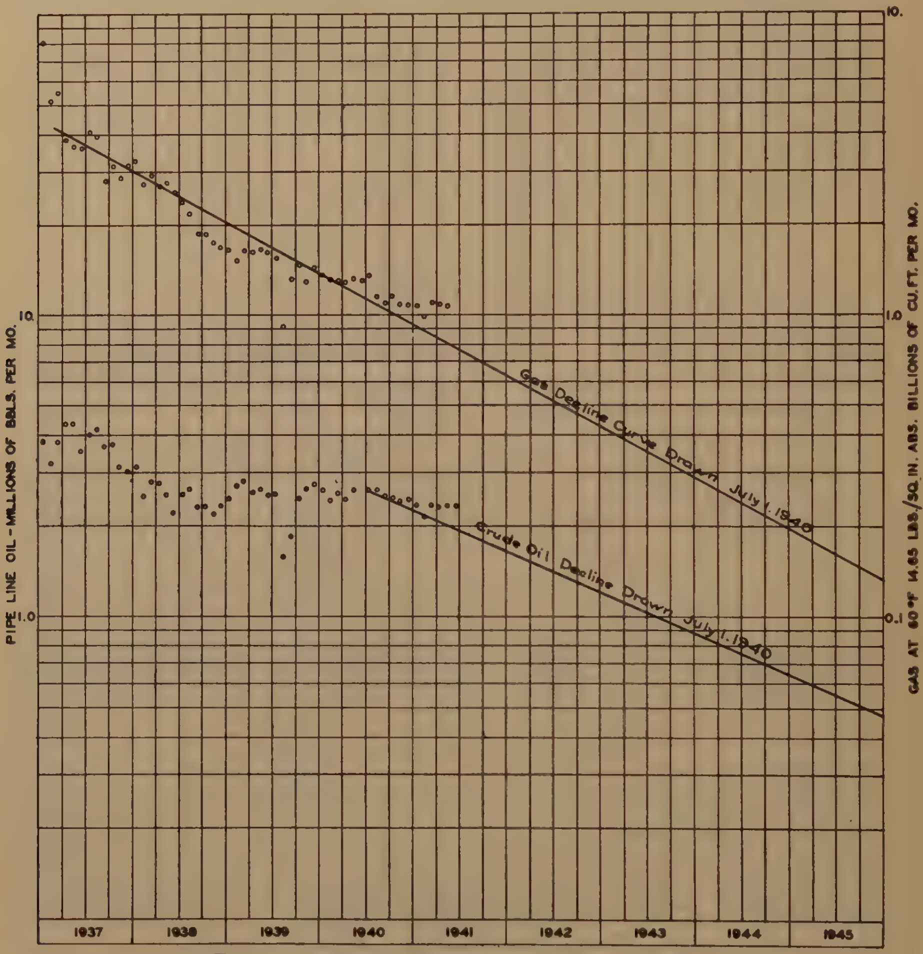

FIG. 4.—OIL AND GAS PRODUCTION DECLINE CURVES.

Gas-oil separators were used during the flowing and gas-lift periods with the major portion of the gas going to the several gasoline plants. At present, casingheads are hooked to the gas lines, with pressures varying from above atmospheric to 4 in.

mercury vacuum. Table 2 contains typical gas analyses in these two periods of production, with gasoline contents ranging from ⅓ gal. of pentanes and heavier for 1000 cu. ft. of separator gas to 2 gal. per 1000 of casinghead gas.

The original oil-water contact was estimated to be at minus 5425 ft. The intersection of the top of the Wilcox with this plane limits the west edge of production indicated on Fig. 2. Water entered the oil-bearing sand in a rather peculiar manner, having detrimental effects on wells completed below minus 5300 ft. as illustrated by Fig. 7. Water entered the most closely drilled areas and the west-edge wells first with a gradual rise in the portion first drilled to about minus 5325 ft. Table 3 gives the results of cooperative surveys on water production, showing that more than one-half the wells make water. However, since 1939, no noticeable rise has occurred in the level at which water is found, although the recent survey indicated a small rise in water production offsetting the previous decline.

TABLE 3.—*Water Production from Wilcox Sand*

Date of Survey	Number Wells Making Water	Water Production, Bbl. per Day
April 1, 1938......	184	17,700
May 15, 1939......	178	12,690
Aug. 15, 1940......	175	10,900
March 15, 1941....	229[a]	11,994
July 1, 1941.......	241[b]	14,660

[a] 156 wells making over 10 bbl. per day.
[b] 169 wells making over 10 bbl. per day.

INITIAL OIL AND GAS CONTENT OF RESERVOIR

Since the crude oil remaining for possible secondary recovery depends on the initial content, extreme care was exerted in establishing the most reliable figures. The initial residual oil content of 1080 million barrels calculated in 1935[1] by the material balance method, using solubility and shrinkage data, was roughly twice that predicted from the then known sand volume and porosity data.

The initial oil and gas contents were recomputed with calculations shown in Table 4. Such items as initial reservoir pressure, presence of a gas cap, solubility data, gas production, were carefully scrutinized. The initial reservoir pressure was taken as 2686 lb. per sq. in. abs. at minus 5260 ft. subsea, 2630 lb. at 5100 ft., after considering initial casinghead pressures reported at 2300 lb. and plotting reservoir pressure against volumetric withdrawal. The presence of an initial gas cap was shown from newspaper reports on the Mary Sudik discovery well. Its size was determined by plotting early gas-oil ratios against depth at which wells penetrated the top of the Wilcox. The crosshatched areas of Fig. 2 along the eastern edge of the Wilcox area show the extent of the gas cap measured by the gas-oil ratios. The volume of gas contained in the sand estimated to be a gas cap is 10.3 billion cu. ft. at 60°F. and 14.65 lb. per sq. in. abs. The original solubility and shrinkage data of Lindsly[5] were reexamined and the curves of Fig. 5 were plotted.

Table 4 gives the computations at seven annual intervals of the initial oil and gas content when assuming the reservoir volume a constant. Items 1 through 7 are given or are obvious. Item 8 is the product of crude-oil production and 735 cu. ft. per bbl. as solution gas either by differential vaporization at 132°F. or by flash vaporization in separators. Item 9 is taken from Fig. 6, which gives compressibility factors calculated from gas compositions occurring at the reservoir pressures. Item 10 is the initial gas-cap gas that left the reservoir as the pressure dropped to the pressure of item 3. Item 11 equals item 2 minus the sum of items 8 and 10. Item 13 equals item 1 times 5.61 and times 1.361. Item 14 equals item 7 divided by item 5 and multiplied by 5.61. Item 15 is item 11 times item 14. Item 16 equals items 13 plus 15. Item 20 is item 19 divided by item 5. Item 21 is item 11 divided by item 5. The calculated average quantity of initial residual crude oil is 1072 million barrels.

TABLE 4.—*Computation of Initial Quantity of Wilcox Crude Oil, Entire Pool*
CALCULATIONS MADE FROM RESERVOIR CONDITIONS AT INDICATED DATES

Item	Units	1-1-33	1-1-34	1-1-35	1-1-36	1-1-37	1-1-38	1-1-39
1. Crude oil produced	MM bbl.	69.8	119	166	212	255	301	333
2. Gas produced	MMM cu. ft.	177	378	550	630	701	751	780
3. Bottom-hole pressure	Lb. per sq. in. abs.	1,640	895	430	203	111	58	34.8
4. Gas dissolved in crude at bottom-hole pressure	Cu. ft. per bbl.	487	308	198	132	94	57.5	32
5. Gas evolved initial condition to bottom-hole pressure	Cu. ft. per bbl.	248	427	537	603	641	677.5	703
6. Shrinkage crude from bottom-hole pressure to atmospheric	Per cent	26.0	18.9	14.2	11.3	9.4	7.7	6.2
7. Shrinkage crude from initial pressure to bottom-hole pressure	Per cent	10.1	17.2	21.9	24.8	26.7	28.4	29.9
8. Solution gas for produced crude	MMM cu. ft.	51.3	87.5	122	156	188	222	245
9. Compressibility factor reservoir gas	Ratio	0.82	0.885	0.926	0.955	0.97	0.985	0.99
10. Gas from initial gas cap	MMM cu. ft.	4.0	7.1	8.8	9.6	9.9	10.1	10.2
11. Excess gas produced	MMM cu. ft.	121.7	283.4	419.2	464.4	503.1	518.9	524.8
12. Volume 1 std. cu. ft. gas at reservoir conditions	Cu. ft.	0.0083	0.0165	0.0359	0.0785	0.146	0.283	0.475
13. Volume produced oil and dissolved gas	MM cu. ft.	533	910	1,270	1,620	1,950	2,300	2,540
14. Initial volume excess gas in liquid state	$\frac{\text{Cu. ft.}}{\text{Std. cu. ft.}}$	0.00228	0.00226	0.00229	0.00231	0.00234	0.00235	0.00238
15. Initial volume excess gas	MM cu. ft.	277	640	961	1,072	1,178	1,219	1,249
16. Reservoir volume total production oil and gas	MM cu. ft.	810	1,550	2,231	2,692	3,128	3,519	3,789
17. $a = \frac{16}{12}$	MMM cu. ft.	97.6	94.0	62.1	34.3	21.4	12.4	8.0
18. $\frac{1}{b} = \frac{14}{12}$	Ratio	0.275	0.137	0.064	0.029	0.016	0.008	0.005
19. $\frac{a}{1 - \frac{1}{b}}$ = gas-cap gas	MMM cu. ft.	135	109	66	35.4	21.7	12.5	8.0
20. Crude for gas-cap gas	MM bbl.	544	255	123	59	34	18	11
21. Crude for excess gas	MM bbl.	490	664	781	770	785	766	747
22. Total initial crude	MM bbl.	1,104	1,038	1,070	1,041	1,074	1,085	1,091
23. Total initial fluid	MM bbl.	1,503	1,411	1,457	1,419	1,462	1,478	1,487

735 cu. ft. per bbl. residual oil, solubility at 2686 lb. per sq. in. abs., shrinkage 36.1 per cent.
Average initial residual oil, 1072 million barrels, reservoir fluid, 1460 million barrels.

Porosity-sand volume estimates of initial quantity of crude oil are limited by the meager porosity data available (Table 5) and the unknown extent of some undeveloped sand along the west edge. The data on porosity were studied in light of the several strata existing, as shown by Fig. 7. The average porosity for the samples examined is 18.4 per cent and for area 3, by an integration of sand volume and porosity by strata, is 18.2 per cent. The volume of oil and dissolved gas of Table 5 and an estimated Wilcox sand volume above 5425 ft. subsea of 6,903,000,000 bbl. requires a porosity 21.1 per cent for the sand to contain the fluid. Difficult coring operations in the soft sand are likely to have missed the more porous sand. The 18.4 per cent average porosity for the recovered sand from the two wells having full sand sections can be raised to 21.1 per cent for the full sand section by assuming a porosity of less than 23 per cent for the nonrecovered core.

The conclusions of this study are that the 1072 million barrels are in accord with

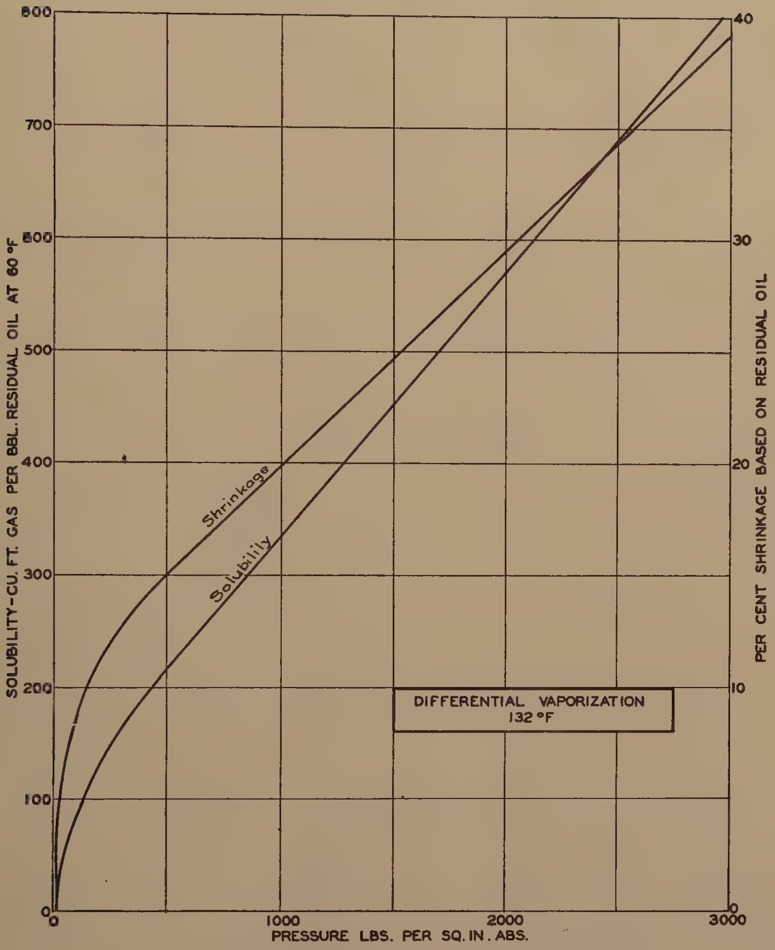

FIG. 5.—SOLUBILITY AND SHRINKAGE CURVES.

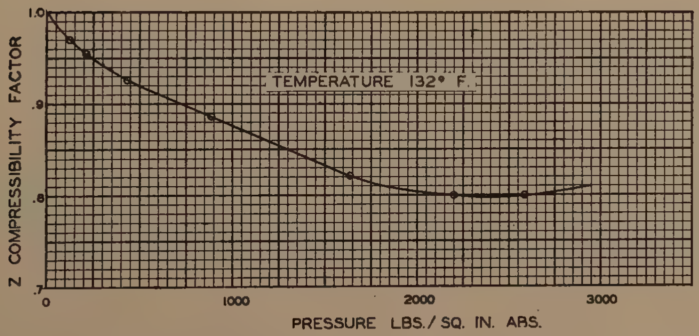

FIG. 6.—COMPRESSIBILITY FACTORS FOR RESERVOIR GASES.

sand volume and porosity information and constitute the most probable quantity of initial residual crude oil.

CONDITIONS IN THE RESERVOIR

Any secondary recovery program must have a more definite knowledge than that a given quantity of oil is in the reservoir. The position of the oil, the percentage saturation of the sand, and presence of water are all important factors in any recovery program. The operators gave the engineers a cue on the problem by their

TABLE 5.—*Summary of Porosity Data on Wilcox Sand*

Company	Lease	Well No.	Stratum	Thickness of Stratum at Well, Ft.	Subsea Depth of Core, Ft.	Feet Cored	Recovery, Per Cent	Number of Porosity Samples	Porosity, Per Cent		
									Low	High	Average
British-American.	Military	2	A	75	5,196–5,221	6.5		8	10.80	19.80	15.90
British-American.	Military	2	B	85	5,319–5,321	2.0		3			
British-American.	Piersol	4	B-2	140	@ 5,326	Bailed		1	13.70	13.70	13.70
British-American.	Hampton	3	B-2	122	@ 5,332	Bailed		1	19.70	19.70	19.70
British-American.	Hampton	2	B-2	141	@ 5,335	Bailed		2	22.10	23.50	22.80
British-American.	Powell	1	B-2	118	@ 5,318	Bailed		2	19.00	20.10	19.60
I.T.I.O.	Wisel	6			5,274–5,284	Bailed		4	13.60	19.05	15.50
I.T.I.O.	Wisel	3			5,310–5,322	Bailed		2	15.90	17.60	16.75
I.T.I.O.	Little	4	B	80	5,363–5,380	Bailed		2	15.10	17.01	16.05
Phillips	Ashcan	2	D-1	22	@5,267	Boiled		3	15.10	19.30	17.20
Phillips	Beam	1			5,153–5,275	Bailed		5	16.80	24.00	20.78
Phillips	Blazier	1	B	121	5,277–5,282	Bailed		20	10.30	21.60	18.17
Phillips	Brimm	1	B	86	5,148–5,234	86.0	33	24	12.20	24.45	20.18
Phillips	Brimm	1	B-1	6	5,233–5,238	6.0	33	4	21.38	21.95	21.60
Phillips	Brimm	1	B-2	12	5,239–5,251	12.0	85	10	18.31	24.95	20.90
Phillips	Brimm	1	C	9	5,253–5,262	9.0	92	7	15.15	22.50	19.79
Phillips	Brimm	1	D	24	5,262–5,286	24.0		5	18.61	23.25	20.74
Phillips	Brimm	1	D-1	30	5,285–5,293	8.0		8	15.01	21.70	19.24
Phillips	Great West.	1	A	55	5,128–5,132½	4.5	100	6	16.80	20.10	18.65
Phillips	D. F. Sawyer	1	A	70	5,209–5,212	4.0	100	8	17.10	18.90	17.73
Phillips	Stiles	6			Unknown	Bailed		5	14.30	19.70	18.06
Phillips	Stiles	7	B	38	5,241–5,251	Bailed		12	18.20	24.30	21.86
Phillips	Stiles	7	B-1	8	@ 5,256	Bailed		2	15.60	16.70	16.40
Phillips	Stiles	7	B-2	42	5,261–5,291	Bailed		32	11.90	23.20	18.56
Phillips	Stiles	7	C	8	@ 5,301	Bailed		8	11.30	20.80	16.50
Phillips	Stiles	7	D	61	@ 5,314	Bailed		5	9.60	23.40	18.10
Phillips	Stiles	8	A	65	5,155–5,214	17.5	58.3	76	8.50	19.30	14.60
Phillips	Stiles	8	B	30	5,220–5,223	2.5	6.25	2			
Phillips	Stiles	8	B-2	32	5,271–5,310			176	9.60	25.70	20.06
Phillips	Stiles	8			Above 5,318			11	10.10	21.40	15.50
Phillips	Stiles	8			Above 5,325			14	8.30	19.30	12.94
Phillips	Wallace	2	B-4	42	5,200–5,211			3	21.70	23.70	23.00
Phillips	Wallace	2	C	5	5,217–5,222			1	11.50	11.50	11.50
Phillips	Wallace	2	D	38	5,212–5,262			21	10.80	23.30	17.93
I.T.I.O.	Mary Sudik	1			5,142–5,151	9.0		7	12.90	19.30	15.90

TABLE 6.—*Saturation Data on Wilcox Cores from Newly Drilled Wells*

Well	Core from Stratum, Zone		Number of Samples	Porosity, Per Cent	Permeability, Millidarcys	Oil Saturation, Per Cent		
						Low	High	Average
A	A	Gas	60	14.6	410	1.0	26	7.2
	B	Oil	150	20.5	1,143			92.8
B	A	Gas	130	16.8	628	3.0	20.2	9.5
	B	Oil	45	18.3	993			79.6
C	A	Gas	6			5	21	
		Gas	8	17.1	513			16.1
D	A	Gas		8.5–19.6		20.3	25.9	
	A	Oil		14.7	43			52.7
E	B	Oil	46	19.1	1,280			78.
			13	19.0	1,040			84.1
	C or D	Oil	5	12.7	204			54.5

constant reference to "fluid levels" in producing wells.

General knowledge of a gas drive removing oil from sands would indicate a liquid saturation of 40 to 50 per cent in the upper portion of the reservoir with increasing saturation in the lower part of the reservoir. Examination of the facts involved proved otherwise. Core data on some of the newly drilled wells showed an oil-gas contact to exist over the range of a few feet. Table 6 shows core data obtained on cores or bailer samples recovered before and after reaching the oil-gas contact. The stratum from which the specimen was obtained is listed in accord with the symbols of Fig. 7. Special efforts were made to get uncontaminated sand and to improve coring and sampling technique. The table shows oil saturations in the gas zone of 1.0 to 25.9 per cent and oil saturations of 52.7 to 92.8 per cent of the pore space in the sand below the oil-gas contact.

Determinations of connate water were made on an early core taken with Aquagel[6] and on a newly drilled well without water in the hole. The former indicated 0.3 to 0.8 per cent of pore space to be connate water and 147 samples from the latter averaged 2.6 per cent of pore space as total water or 0.6 per cent connate water calculated from chloride contents of Wilcox brine. Other water contents ranged from 1 per cent to over 50 per cent but the samples were taken in the presence of water. The data indicate a possibility of 1 per cent or even no connate water in the sand.

An attempt to relate the core data and the apparent separation of the reservoir into a gas cap and an oil-saturated zone with other information on oil drainage from sand revealed the following: Tests in two laboratories[7,8] on the drainage of oil from nonconsolidated sand showed a low saturation in the upper portion of the sand (Fig. 8). Computation of oil saturations based on Leverett's paper[9] gave the

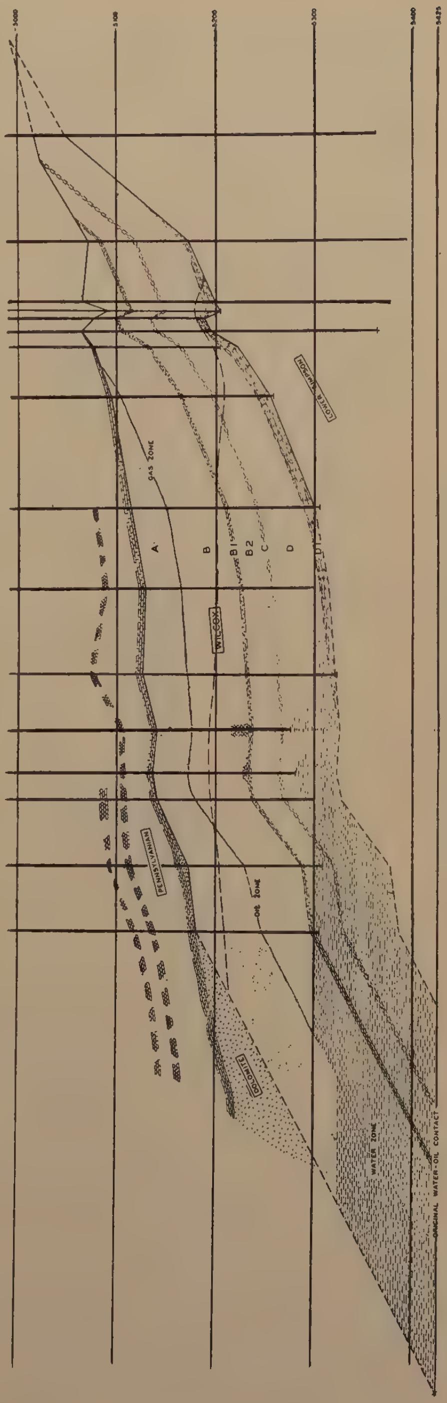

FIG. 7.—DIVISION OF WILCOX SAND INTO STRATA.

curve of Fig. 8. Not satisfied with the positive evidence that the indicated drainage would occur in consolidated sand, a test was made on pieces of consolidated sand from the outcrop.

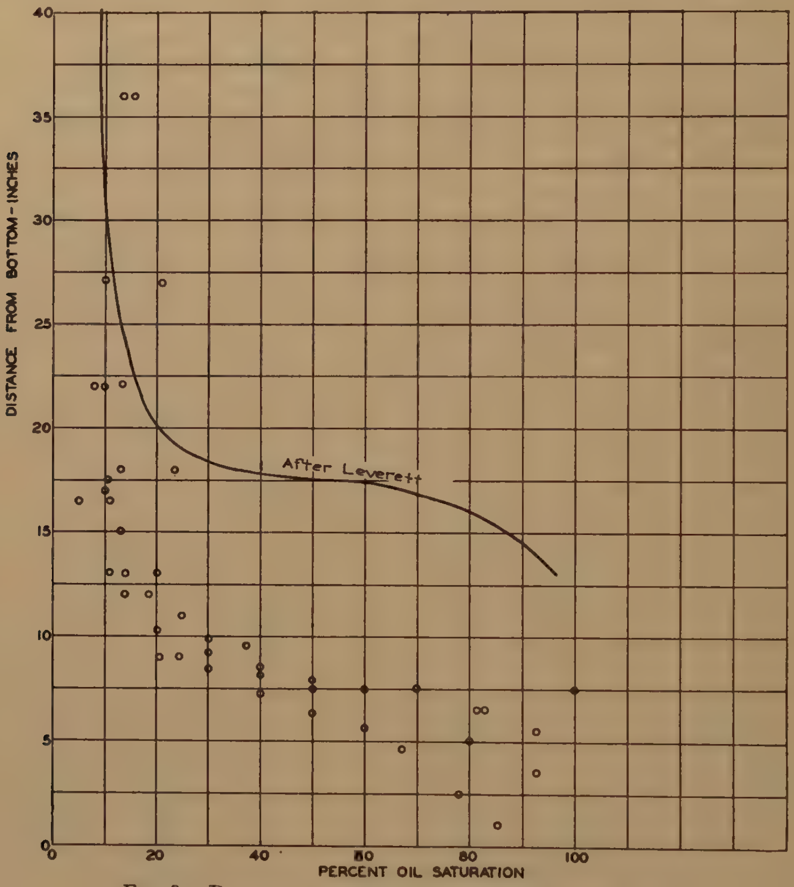

Fig. 8.—Drainage of oil from nonconsolidated sand.

Outcrop Wilcox sand was sawed into blocks, sections 3 in. square and lengths varying from 8 to 14 in. Six pieces were joined by nonconsolidated sand, paper was wrapped at the joints and they were placed in a 5⅝-in. pipe (Fig. 9). The sand was sealed in place by a quick-setting gypsum (Calseal) cement and dried for about 24 hr. by dry propane passed through the core. Wilcox crude and kerosene having a viscosity of 2.1 centipoises at 83°F., which is equivalent to the viscosity of Wilcox crude at 130°F. (41.7°A.P.I., 25.7 dynes per cm. surface tension), was used to saturate the sand by displacement of oil up through the sand. The oil was allowed to drain at room temperatures varying from 79.5° to 85.5°F., giving the usual declining rate curve and a noticeable influence of 2° or 3°F. on the drainage rate. At the end of 15.6 days, the pipe was cut into rings 1 to 3 in. wide and the sand was removed to sealed bottles. The oil-saturation results determined by W. S. Walls are shown by Fig. 10. The consolidated sand had an average porosity of 15.6 per cent and permeability of 628 millidarcys and more nearly represents the "tight" sand of stratum A in Fig. 7 than the "loose" sand of stratum B in the reservoir. The low saturations of 6 to 8 per cent of the pore space filled with oil in the top section of the consolidated sand was positive proof of the ability of natural drainage to lower the oil content below that to be recovered by any other commercial method.

The reservoir was studied with regard to the "fluid level" reports from the field. Fig. 11 shows the best data for a given area that were available to give a decline curve. The level at which crude oil was encountered while drilling in, the level from subsurface pressures, and the bottom of wells at the base of the sand that went off production because of the receding oil were used to indicate the oil-gas contact. This scattering of points shows a relatively wide variation in the "oil level," but for July 1, 1940 should have given a fairly general average for the area. Similar curves for the other areas fixed oil-gas contact levels as of July 1, 1940 as tabulated in Table 7.

Using these liquid-gas contact data, the information on water intrusion placed on cross sections similar to Fig. 7, and sand-volume data, the Wilcox sand was divided into zones: gas, oil, and water permeated. Table 7 gives the sand and pore volumes of these zones for the areas studied and Fig. 12 is a representation of the division into zones.

Information as to the effectiveness of water in flooding the sand below the general level to which it had risen comes from calculations shown by Table 8. Percentages of oil saturations were assumed in the gas and oil zones and the remaining oil, after corrections for migration in an area, was converted to percentage saturation. The most probable oil-saturation values of 20 per cent in the gas zone and 85 per cent in the oil zone indicate that slightly less than 50 per cent of the pore space below the top of the water intrusion contains crude oil. Although water has been irregular in its rise, this figure as an over-all average of oil retained is not indicative of any beneficial action by the natural water encroachment.

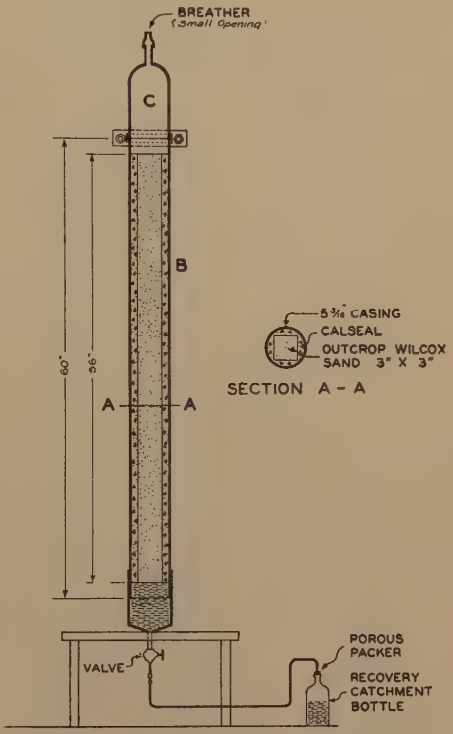

FIG. 9.—GRAVITY DRAINAGE APPARATUS.

During the past year there have been few changes in the oil-water contact observed. However, the gas-oil contacts have lowered as much as 35 ft. in the more productive areas, C, 1 and 2, with little observed change in areas A and B. An average decline of 12 ft. for the entire Wilcox has been calculated for the period of Jan. 1 to July 1, 1941. Some new wells

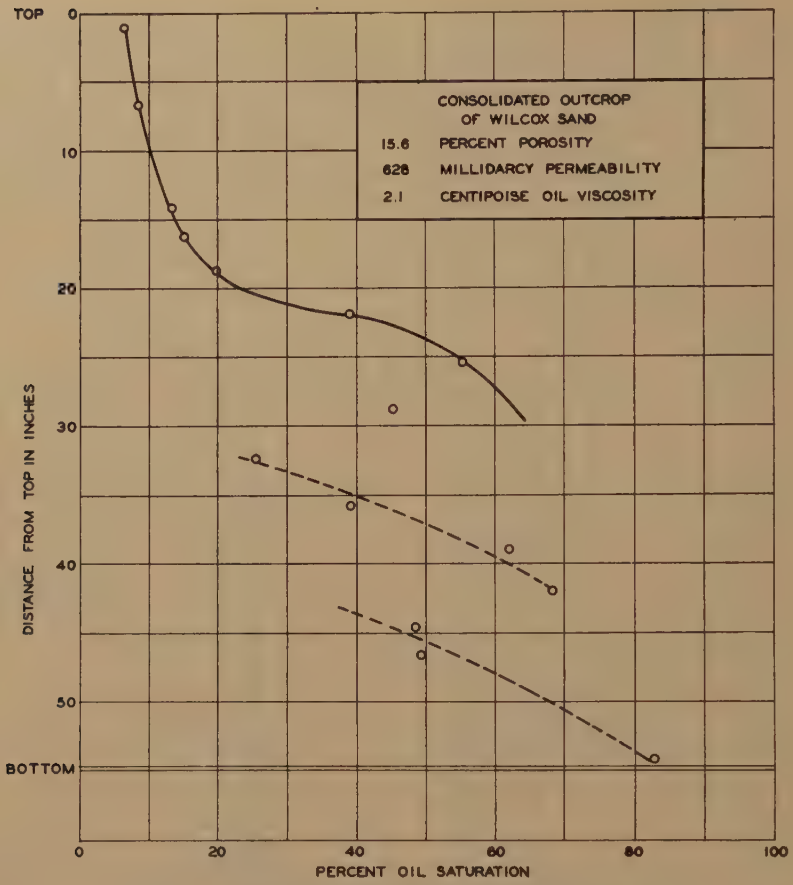

FIG. 10.—SATURATION DISTRIBUTION AFTER DRAINAGE.

TABLE 7.—*Division of Reservoir into Gas, "Oil" and "Water-permeated Zones"*

Area	Gas-oil Contact, Ft. Subsea	Oil-water Contact, Ft. Subsea	Volume of Sand, Million Bbl.			Pore Volumes,[b] Million Bbl.			Total
			Gas Zone	Oil Zone	Water-permeated Zone	Gas Zone	Oil Zone	Water-permeated Zone	
A	5,266	5,275	105.0	22.0	597.0	23.1	4.8	132.0	159.9
B	5,255	5,325	569.0	252.0	258.0	125.0	55.5	56.7	237.2
C	5,220	5,325	288.0	221.0	200.0	63.3	48.6	44.0	155.9
1	5,210	5,302	429.0	328.0	407.0	94.3	72.1	89.5	255.9
2	5,196	5,308	273.0	378.0	418.0	60.0	83.1	92.0	235.1
3	5,244	5,300	132.0	109.0	287.0	29.0	24.1	63.1	116.2
Part[a] of 4	235	5,309	53.3	94.6	172.0	9.9	17.5	31.8	59.2
Total			1,849.3	1,404.6	2,339.0	404.6	305.7	509.1	

[a] North of south line of section 22.

[b] Porosity used: areas A, B, C, 1, 2 and 3, 22 per cent; part of area 4, 18.5 per cent.

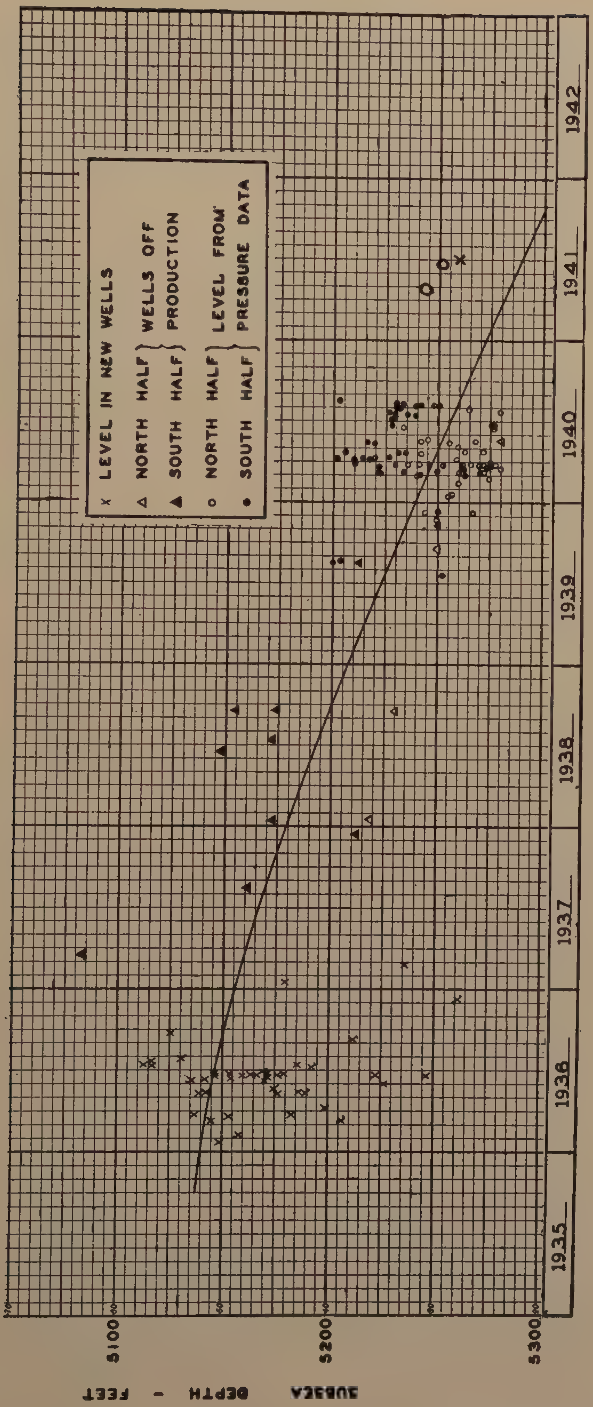

FIG. 11.—GAS-OIL CONTACT IN AREA B.

have been completed in areas abandoned because of the fingering of water and now produce 400 to 500 bbl. of oil per day. Observations made during the past year bear out the general validity of the reservoir conditions just described.

TABLE 8.—*Calculated Oil Saturations of "Water-permeated" Zones*
MILLIONS OF BARRELS

Area	Total Pore Volume[a]	Gross Oil Production	Initial Residual Oil	Remaining Residual Oil[b]	Pore Space in "Water-permeated Zone" Filled with Residual Oil, Per Cent[c]		
					20 % Gas Zone 85 % Oil Zone	40 % Gas Zone 85 % Oil Zone	40 % Gas Zone 60 % Oil Zone
(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)
A	159.9	13.2	117.3	75.7	51.1	48.0	48.8
B	237.2	48.2	174.3	97.6	53.0	12.0	34.8
C	155.9	23.7	114.5	71.4	47.6	20.5	46.4
1	255.9	130.9	188.0	118.4	48.5	29.0	47.6
2	235.1	72.7	172.8	117.7	43.9	31.8	52.9
3	116.2	25.5	85.4	55.9	49.5	40.9	49.9
Part of 4	59.2	23.4	43.5	20.1	13.2[d]	7.9[d]	20.8[d]
Total	1,219.4	337.6	895.8	556.8			

[a] Porosity used 22 per cent areas A, B, C, 1, 2 and 3, 18.5 per cent area 4.
[b] Estimates of oil migration are included.
[c] Reservoir liquid saturation: 20 per cent fluid = 18.7 residual oil.
40 per cent fluid = 37.4 residual oil.
60 per cent fluid = 56.1 residual oil.
85 per cent fluid = 79.5 residual oil.
[d] Migration not included for this area.

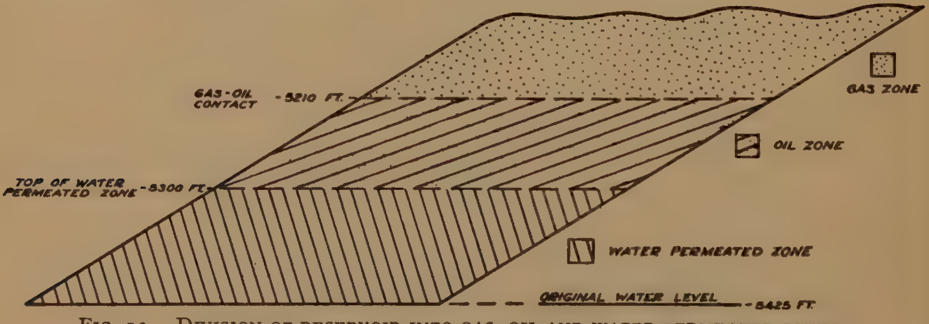

FIG. 12.—DIVISION OF RESERVOIR INTO GAS, OIL AND WATER-PERMEATED ZONES.

OIL RECOVERIES

The amazing feature of the Wilcox sand history has been the high recoveries of oil with continual upward revision of future production estimates. This is due in part to the present low rate of water entrance to the sand following the early rapid rise, partly to the drainage occurring, and more recently to new wells. Attempts have been made to estimate the future oil production by decline curves since proration has ceased to curtail the production for the most part. As of Jan. 1, 1940, the Wilcox sand north of the south line of section 22-11-3 was estimated to produce 73.1 million barrels by this method. Already 41.5 million barrels of this quantity have been produced, leaving 31.6 million barrels of this estimate to be produced after July 1, 1941. In July 1940, a revised estimate gave 92.8 million barrels of future oil, and the production of 27.2 million barrels from July 1, 1940 to July 1, 1941 from this portion of the field leaves 65.6 million barrels as the future production of this estimate. Another estimate using the data to July 1, 1941 predicts by decline curves a future oil production of 79.4 million barrels.

The influence of the 31 wells drilled since Jan. 1, 1940 is obvious when it is known that 16 per cent of the present production comes from these wells. Likewise deepening, cleanouts, and general improvements in pumping operations have prevented the curves for an area from following the usual decline pattern. Difficulties in determining for an area the natural future production as "primary" oil and estimates of "secondary" oil are numerous under these conditions, even though the decline curve may be correct for individual wells or leases. In a good measure, the information for conducting these drilling operations was accumulated in the "secondary recovery" studies but the added production is labeled as natural production because no artificial stimulus is being required to obtain the estimate given by the decline curve. Table 9 lists the estimates of future production as of July 1, 1940 from decline curves for the areas studied and Fig. 4 shows the decline curve for the entire Wilcox sand.

TABLE 9.—*Oil Recoveries by Reduction in Oil Saturations*
MILLIONS OF BARRELS

Area	Pore Volume Oil Zone	Future Primary Oil by Decline Curves	Oil Recovery by Reduction from 85 to 20 Per Cent Saturated above Decline Curve in Oil Zone	Oil Recovery by Reducing Water-permeated Zone to 25 Per Cent Oil
A	4.8	3.19	0.6	33.0
B	55.5	24.6	7.8	15.2
C	48.6	23.6	6.5	9.9
1	72.1	24.3	17.8	21.0
2	83.1	8.6	39.9	17.4
3	24.1	7.6	6.4	15.4
Part of 4	17.5	0.9	9.2	0.
Total	305.7	92.8	88.2	111.9

Estimates of oil recoveries above primary oil by decline curves may be made from estimates of present and final saturations in the reservoir. Table 9 indicates an added recovery of 88 million barrels from the oil zone by reducing the saturation 65 per cent, or from 85 to 20 per cent. Likewise, the water-permeated zone would produce 112 million barrels of oil if its oil saturation could be reduced to 25 per cent of the pore space. A reduction in saturation of 5 per cent in the gas zone would yield 18 million barrels of oil.

WATER-FLOODING

The first report to the Association advocated water-flooding as a secondary recovery method. A careful recount of the facts involved show the following: The natural water drive was very irregular and detrimental to natural production. Drainage of oil has left some of the gas cap with less than 10 per cent of the pore space filled with oil and has accumulated a layer of sand with a high oil saturation. Control of water movement in the highly permeable sand has no indication of being a simple problem, for accidental entrance of water in the reservoir has quickly flooded near-by wells.

With these points adverse to water-flooding, tests were made to investigate the wettability of the Wilcox sand by oil and water.[6,10] Fig. 13 shows the displacement cell used.[10] The usual test was to pack sand containing water in end *B* and sand containing oil in the other end with an oil-water meniscus at *A*. The capillary tube *D* measured the displacement pressure of the water for the oil that occurs if water preferentially wets the sand.

Some 50 runs were made to evaluate wetting characteristics of Wilcox sand as compared to other sands. Table 10 shows the results of displacement tests using outcrop Wilcox sand and tap water. The initial displacing pressure is necessary because placing the stopper and capillary tube in the end of the cell resulted in an initial height of oil in the capillary. Tap water displaced kerosene at a remarkable rate, such as the first 6 in. differential in 10 minutes.

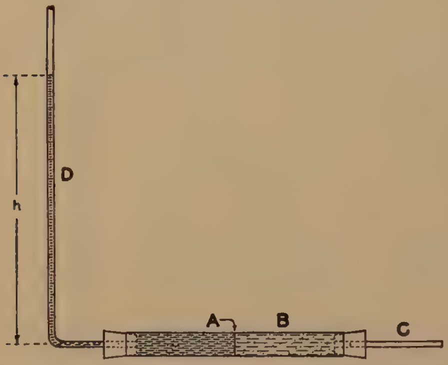

Fig. 13.—Arrangement of displacement cell.

Table 11 shows data on displacing crude oils with water from the same reservoir and using the indicated sand. In no case could Wilcox water be made to displace Wilcox crude from clean or reservoir sand. Table 12 shows results of treating sand upon the displacing ability of tap water for kerosene. The data show that washing dry clean sand in Oklahoma City Wilcox crude did something to the sand to remove the preferential wetting of tap water over kerosene. Other crudes evidently had some effect on the dry sands, but not to the same degree as the Oklahoma City Wilcox crude.

The outcrop sand packed in the cell had an average pore radius of 0.00267 cm. as measured by displacement pressures with benzene, butyl acetate and water. The surface tension of the kerosene was 25.6 dynes per cm. at 82°F., of Wilcox water was 77.0 dynes per cm. at 90°F. and of O. C. Wilcox crude was 23.3 dynes per cm. at 89°F.

Tests of this nature are not conclusive as to the wettability of the reservoir sand by native oil and water because of meager experience with them, but they do indicate that O. C. Wilcox sand may not be preferentially wet by Wilcox water. The low content of connate water, or absence of connate water in the sand is in accord with this finding. Also, the lack of beneficial results from natural flooding points to the same conclusion—that there is no assurance that a water drive in the O. C. Wilcox sand would recover the desired crude oil.

In order that water injection might be given full consideration, the expected yields and economical angles were considered. The large number of input wells required and the costs of handling water became apparent. Fig. 14 shows a typical electrolytic flooding diagram prepared to show possible lines of water advance for a given set of wells and assuming uniform sand thickness, resistance, and other properties. The raising of the oil-gas contact seemed undesirable because the gas zone already contained less oil than would be left if water were used to remove it. The net result of such considerations was that oil recovery by water drive with present knowledge was impractical and uneconomical.

Gas Injection

The injection of gas to raise the reservoir pressure above atmospheric has merit from several angles. The drainage of the oil from top to the bottom of the sand is the most important phenomenon in the recovery process. Gas evolution from crude oil causes rapid increases in viscosity and surface tension, which retard the drainage process. Gas-pressure differentials will force oil from one position to another, but are not likely to move liquid from the well drained portion of the gas zone or cap.

TABLE 10.—*Displacement of Oils from Outcrop Sand by Tap Water*

Run No.	Oil	Temp. °F.	Displacing Pressure in Inches of Fluid Displaced: Beginning	Time Hrs.	End
1	Kerosene	88	-	16.0	12.70
11	Oklahoma City Wilcox	94-88	2.50	15.0	3.50
15	Pawhuska	90-94	7.20	3.4	8.00
16	"	90-94	1.05	6.5	6.00
26	Burbank	87	1.30	5.5	2.38
27	Oklahoma City Wilcox	86-87	1.60	18.0	6.24
30	Earlsboro Wilcox	87	0.10	1.0	0.60*
32	" "	88	1.40	0.5	2.00*
35	Oklahoma City Johnson	83-85	0.80	9.2	3.40
38	East Texas	79-80	2.60	17.5	5.60

*Reading reaches maximum and comes down, probably due to channeling.

TABLE 12.—*Effect of Treatment of Sand Surface on Displacement of Kerosene by Tap Water*

Run No.	Sand	Treatment	Temp. °F.	Displacing Pressure in Inches of Fluid Displaced: Beginning	Time Hrs.	End
1	Outcrop Wilcox	None	88	-	16.00	12.70
3	" "	"	89	6.60	6.00	12.70
4	" "	"	89	5.70	1.50	11.60
8	" "	Soaked in O.C. Wilcox crude, washed with natural gasoline, dried.	-	1.60	1.00	1.50
9	" "	Soaked in benzene & dried	93	5.50	0.75	10.30*
10	" "	Soaked in natural gasoline and dried	94	5.00	1.30	12.00
19	" "	Soaked in O.C. Wilcox crude, washed with natural gasoline, dried.	90	1.50	0.75	1.30
22	Bartlesville core	Crushed, washed water, acetone, natural gasoline and benzene, dried.	89-92	3.40	9.00	5.75
23	O. C. Wilcox	Crushed, extracted benzene 30 hrs., dried.	86	2.25	1.00	2.10
24	Bartlesville	Crushed, extracted benzene 48 hrs., dried.	86	2.65	1.20	2.63**
25	Billings, Wil.	Crushed, extracted benzene 30 hrs., dried.	86	0.80	2.20	1.15
34	Outcrop Wilcox	Soaked kerosene, washed natural gasoline & benzene	85	-	10.00	6.20*
36	O. C. Wilcox	Extracted benzene 30 hrs., dried, washed tap water, dried.	78-82	1.00	4.30	1.15
37	Bartlesville	Extracted benzene 48 hrs., dried, washed tap water, dried.	78-82	1.00	4.50	11.75
40	Outcrop Wilcox	Wet tap water, stirred with Wilcox crude, washed natural gasoline and benzene, dried.	79-80	1.10	5.00	8.25*
41	Billings Wil.	Extracted benzene 30 hrs., dried, washed tap water, dried.	79-81.5	1.65	9.50	2.73
42	Outcrop Wilcox	Soaked Billings crude, washed natural gasoline, dried.	81-81.5	2.65	4.50	3.26*

* Probably not at equilibrium
**Tube not well packed, shaly

Entrance of water into the reservoir may be associated with reservoir pressure and may be retarded by an increase in reservoir pressure. The raising of the pressure to have all natural-gas gathering lines above atmospheric pressure will eliminate the oxygen, which causes corrosion and which is now present under vacuum-line conditions, and especially owing to cleaning out of wells with some wellheads at 2 to 4 in. vacuum.

TABLE 11.—*Displacement of Reservoir Oil with Reservoir Water*

Run No.	Reservoir Fluids	Sand With Treatment	Temp. °F.	Displacing Pressure in Inches of Fluid Displaced: Beginning	Time Hrs.	End
5	O. C. Wilcox	O. C. Wilcox bailer washed natural gaso.	88-96	2.00	7.3	0.70
6	O. C. Wilcox	Outcrop Wilcox	88-96	0.70	7.3	0.40
18	O. C. Johnson	Outcrop Wilcox	90	3.62	2.3	3.87
28	O. C. Wilcox	Outcrop Wilcox	87-88	1.10	2.2	0.90
29	Billings Wil.	Outcrop Wilcox	88	0.45	15.0	2.63
39	East Texas	Outcrop Wilcox	79-80	1.75	17.2	3.00
44	O. C. Wilcox	Reservoir O. C. Wilcox extracted benzene 30 hrs.	78-80	1.88	4.0	1.28

A gas-injection project in the south end of the Wilcox sand not studied in detail by the Association, areas 5, 6 and 7, has given favorable results. The oil-decline curve shows a flattening after gas injection and the increased recovery over a 19-month period of gas injection based on these decline curves is ½ million barrels of oil. About ⅔ of the produced gas was returned to high-input wells for a total input of about 3 billion cubic feet. The reservoir pressures in this portion of the field have remained substantially constant with no vacuum at casingheads.

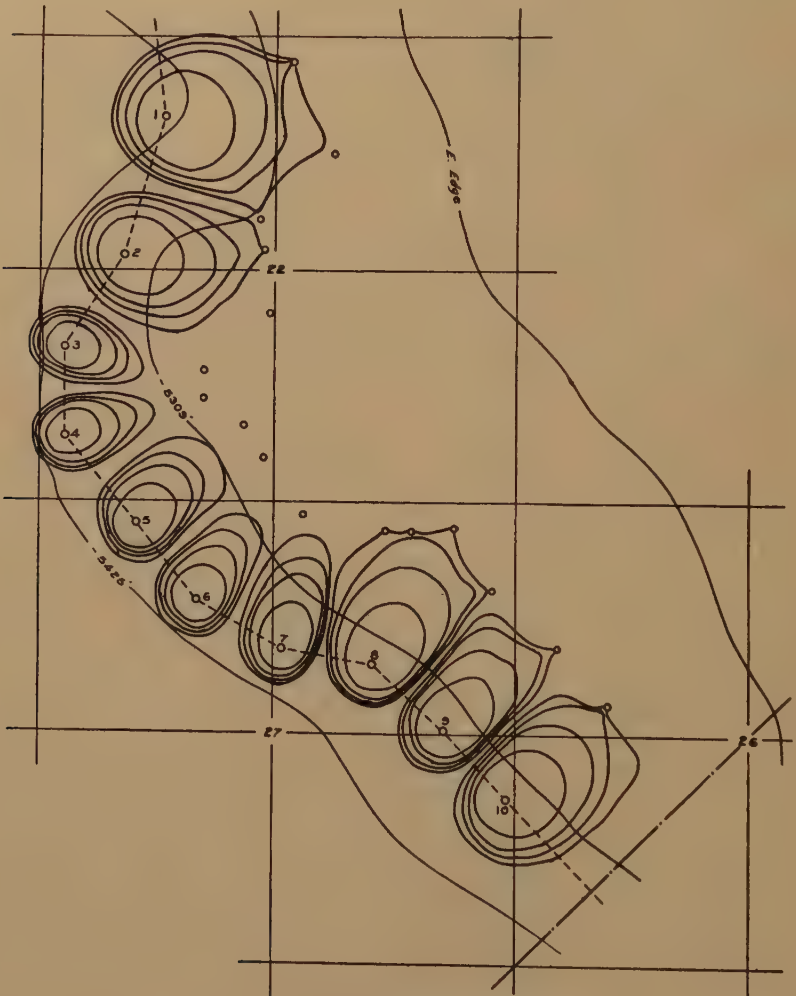

FIG. 14.—WATER-INJECTION PATTERN.

In the area under study, several small gas-injection projects have been tried, some without success in increasing oil recovery and some with apparent increases of oil. The universal problem in all such studies has been the unknown effect of reconditioning and deepening of wells that have accompanied most operations in the area under study. The experience with gas to date would lend encouragement to such a project.

GAS INJECTION AND UNITIZATION

Gas injection of any magnitude would require unitization of the leases in a continuous section of the sand. Operation of a large section of the reservoir as a unit, such as section 15-11-3 and all of the area north of this natural barrier, has great possibilities of increasing the recovery of crude oil. Unitization with broad control of operations along with injection of gas to provide improved conditions for the drainage of the oil down toward the oil-water contact was estimated to increase the ultimate recovery 80 million barrels above that predicted from decline curves as of July 1, 1940. The exact proportion of this recovery that may be attributed to the gas injection and that due to unit operation is difficult to say. This estimate of 80 million barrels of extra crude oil is based on reducing the oil-zone saturation by some 65 per cent for the primary oil plus the secondary oil. This figure may appear high, but the same recovery can be estimated from another procedure too detailed to explain here, which requires a

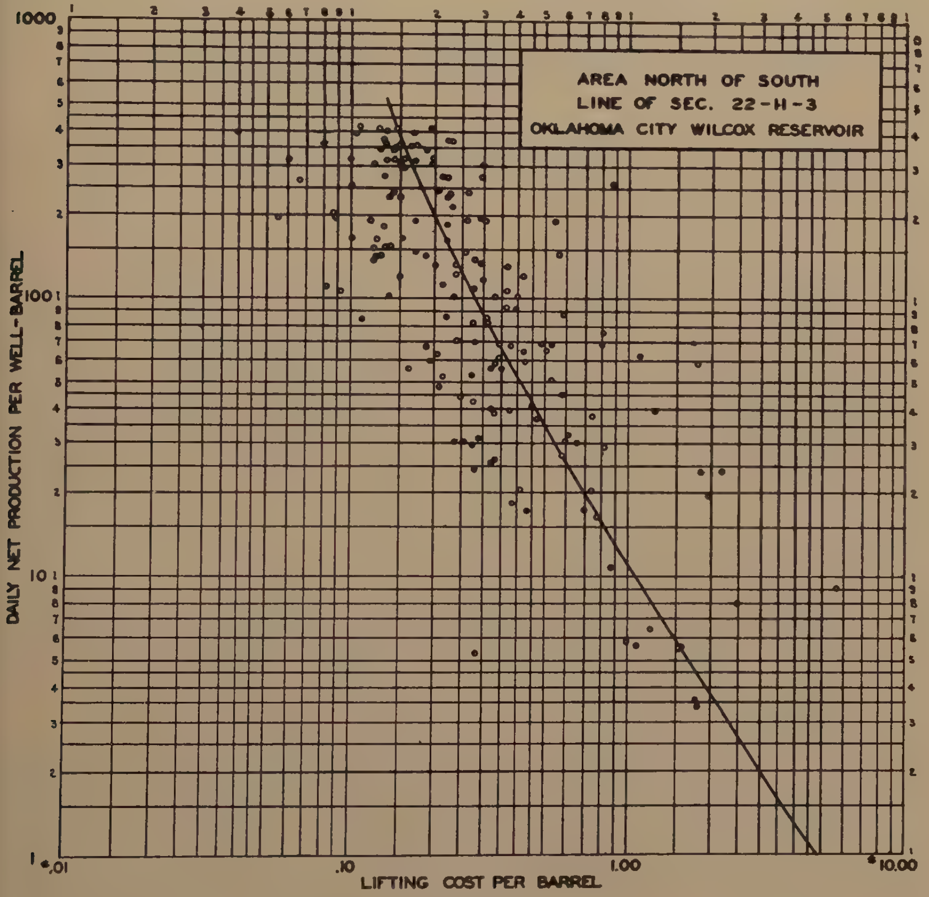

FIG. 15.—FIELD LIFTING COSTS.

reduction in saturation of only 50 per cent of the pore space of the oil zone plus some from the draining gas zone and the top portion of the water-permeated zones.

An economic study was made of the proposed unitization project to recover 80 million barrels of crude oil above the primary oil by decline curves. It was necessary to set up the rate of production, number of operating wells, gas purchases, lifting costs, and other factors for present as well as for unitized operations. Fig. 15 shows the lifting costs under competitive operations. Table 13 gives the estimated earnings from unitization and gas injection. For brevity, only the conclusions of this study are presented.

TABLE 13.—*Estimated Cost and Earnings by Unitization and Gas Injection*

Years	(1) Pipe Line Runs-Bbls.	(2) 7/8 Pipe Line Runs Bbls.	(3) No. of Pro-ducing Wells	(4) Average Pipe Line Runs Per Well Per Day Bbls.	(5) Per Well Lifting Cost Per Month	(6) Total Yearly Lifting Cost	(7) Total Gas Cost @ $0.06 per M.Cu.Ft.	(8) Total Expense	(9) Total Earnings**	(10) Total Earnings Less Expense
1940*	14,030,000	12,276,250	400	194	$447	$1,077,271	$ -	$ 1,077,271	$ 13,012,825	$ 11,935,554
1941	27,202,000	23,801,750	384	194	447	2,059,776	1,651,620	3,711,396	25,229,855	21,518,459
1942	26,010,000	22,758,750	367	194	447	1,968,588	1,292,820	3,261,408	24,124,275	20,862,867
1943	24,915,000	21,800,625	352	194	447	1,888,128	1,238,400	3,126,528	23,108,663	19,982,135
1944	23,875,000	20,890,625	337	194	447	1,807,668	1,186,740	2,994,408	22,144,063	19,149,655
1945	18,920,000	16,555,000	305	170	438	1,603,080	940,500	2,543,580	17,548,300	15,004,720
1946	12,615,000	11,038,125	261	132	416	1,302,912	627,060	1,929,972	11,700,413	9,770,441
1947	8,420,000	7,367,500	223	99	391	1,046,316	418,560	1,464,876	7,809,550	6,344,674
1948	5,600,000	4,900,000	190	81	374	852,720	278,340	1,131,060	5,194,000	4,062,940
1949	3,729,000	3,262,875	160	62	351	673,920	185,400	859,320	3,458,648	2,599,328
1950	2,494,000	2,182,250	133	51	336	536,256	123,960	660,216	2,313,185	1,652,969
1951	1,662,000	1,454,250	109	42	321	419,868	82,620	502,488	1,541,505	1,039,017
1952	1,110,000	971,250	88	35	309	326,304	55,200	381,504	1,029,525	648,021
1953	743,500	650,563	69	30	300	248,400	36,960	285,360	689,597	404,237
1954	492,700	431,113	52	26	291	181,584	24,480	206,064	456,980	250,916
1955	328,200	287,175	37	24	288	127,872	16,320	144,192	304,406	160,214
1956	218,500	191,188	27	22	283	91,692	10,860	102,552	202,659	100,107
1957	145,400	127,225	20	20	280	67,200	7,260	74,460	134,859	60,399
TOTAL	172,510,300	150,946,514				$16,279,555	$ 8,177,100	$24,456,655	$160,003,308	$135,546,653
		Correction for Power				1,415,793		1,415,793		1,415,793
		Corrected Value				$17,695,348		$25,872,448		$134,130,860

* For last half of 1940

** Oil at $1.06 per bbl.

The income less lifting and gas cost for competitive operations to recover 92 million barrels of primary oil from the portion of the field north of south line of section 22-11-3 was estimated as $60,500,000. The income less lifting and gas cost for gas injection and unitization (Table 13) was estimated as $134,100,000, or an increase in earning of 73 million dollars. The total gas to be purchased on the project was 136 billion cubic feet, which would have raised and maintained a reservoir pressure of 35 lb. gauge.

In addition to this recovery of oil, the oil in the water-permeated zone has possibilities of recovery. It is known that both water and oil will drain from the sand[8] in a manner similar to drainage of oil alone. Removal of 14,000 bbl. of water per day, the present rate for the entire Wilcox sand, plus the accumulated water of about 200 million barrels in the area studied, would bring over 100 million barrels of additional oil into the realm of possible recovery. Enough information is not available on the behavior of the water in the water-permeated zone to state that this additional oil could be recovered. Unit operation is necessary for any program that would bring economical recovery of this oil into the realm of possibility.

LEGISLATIVE PROBLEMS

A legal study of the secondary-recovery project was made for the Association* to parallel the engineering work. Although unitization might be possible with existing Oklahoma laws, it appeared essential to have legislation to ensure satisfactory operation of a secondary-recovery project in the Oklahoma City Wilcox sand.

A bill was prepared for presentation to the legislature but conflicting interests and difficulty in a complete understanding of the problems delayed submission of the bill until close to the end of the session in May 1941. The bill proposed to give authority to the Corporation Commission to grant the majority in interest the right to organize a secondary-recovery unit. The necessary majority in interest varied from 99 per cent of the operations when 75 per cent of the primary oil was produced and dropped to 75 per cent when 100 per cent of the primary oil was produced. The organization of a unit would include estimates of future recovery of primary oil and gas that each operator in the field was to receive from the unit. The small minority of operators who were unwilling to join such a project would turn their properties over to the unit for operation and receive the predicted oil and gas for their wells less a lifting cost. Those joining in the unit likewise would receive their share of the primary oil but also share in the secondary oil recovered and bear a proportionate amount of the operation expenses. The bill was not enacted because of the lateness of its submission, making the task of unitization of the major part of the field a practical impossibility until legislation is passed or until depletion brings about cooperative efforts.

The passing of time does increase the accuracy of estimates of primary oil by decline curves but is also causing abandonment of wells that might be useful in secondary operations. A cooperative small-scale project is under discussion for section 22-11-3 since the area is nearing depletion.

Future plans for secondary-recovery operations to recover these estimated millions of barrels of oil are indefinite because legislation to authorize unitization by a majority in interest is lacking. Ample engineering evidence is available that the operation of the Wilcox sand as a unit would enhance the oil recovery and economic return to the royalty owners, to the State of Oklahoma, and to the operators once the legal barriers were removed.

ACKNOWLEDGMENT

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DISCUSSION

(*J. U. Teague presiding*)

D. L. KATZ.—In the absence of Dr. Bartell* and Dr. Benner,† I would like to present the following note, prepared jointly with them.

The results in this paper led to the measurement of a few interfacial contact angles of some crude oils and reservoir waters on quartz plates and tips. Fig. 16 gives certain contact-angle measurements for quartz-crude-oil-reservoir-water systems and also for a system of quartz, iso-octane and distilled water, as follows:

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a. A quartz plate was covered with Oklahoma City Wilcox water and a droplet of Oklahoma City Wilcox oil was brought into contact with the plate. The photograph taken after about 2 hr. shows a 60° contact angle, as measured through the water phase. The angle had increased slightly with standing but appeared to have reached an equilibrium value before the photograph was taken.

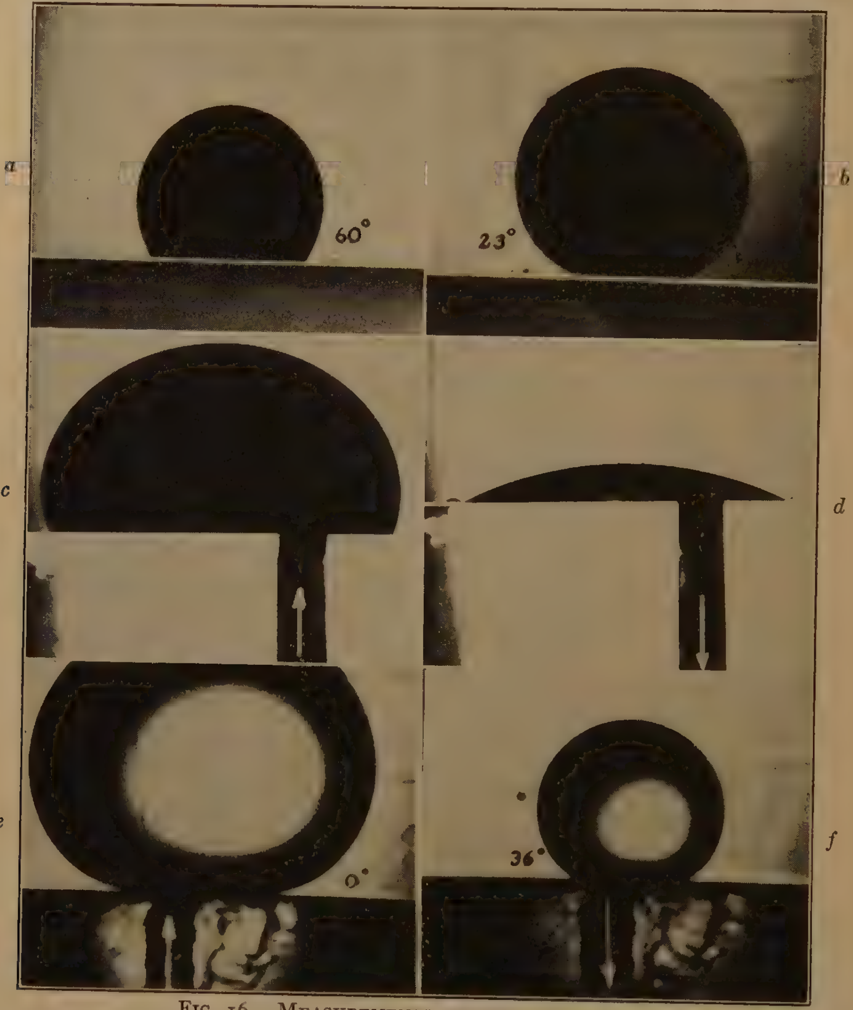

Fig. 16.—Measurements of contact angles.
a. O. C. Wilcox crude oil in O. C. Wilcox water.
b. East Texas crude oil in East Texas water.
c. O. C. Wilcox crude oil in O. C. Wilcox water (oil in).
d. O. C. Wilcox crude oil in O. C. Wilcox water (oil nearly out)
e. Iso-octane in distilled water (iso-octane in).
f. Iso-octane in distilled water (iso-octane out).

b. The procedure of test *a* was repeated, using East Texas water and crude oil. The contact angle through the aqueous phase is 23°.

c. Oklahoma City crude oil was forced out through a capillary channel onto the surface of a fused quartz plate immersed in Oklahoma City Wilcox water. The contact angle measured through the aqueous phase was 55°. This test is in principle the same as test *a*, using different technique.

d. The droplet formed in test *c* was reduced in size by withdrawing the oil through the capillary. The contact angle increased to 180°, measured through the water phase; the photograph of Fig. 16*d* was taken before the oil was completely withdrawn.

e. Pure iso-octane was forced out through the capillary onto the surface of a fused quartz plate immersed in redistilled water. The contact angle measured through the water phase was zero.

f. The droplet formed in test *e* was partially withdrawn. A stable contact angle of 36° was obtained, as indicated in Fig. 16.

Photographs *c* through *f* were taken upside down.

The behavior exhibited by the silica-crude-oil-reservoir-water systems is seen to be quite different from that for the system of silica, iso-octane and pure water.

In experiments *a*, *b*, *c* and *e*, in which the solid was initially wet by the water, it can be noted that the solid shows a preferential wetting by the water when oil or octane is brought into contact with the solid. It is of some significance, however, that a zero contact angle was formed between silica, iso-octane and water, whereas both of the crude oils form a definite, finite and measurable contact angle with the silica and reservoir water.

Experiments *d* and *f* are even more striking in illustrating differences in behavior between systems of pure liquids and reservoir fluids. Water indicated no tendency to remove oil from the surface of silica in test *d*; even though the quartz surface was initially wet by water, contact of the solid with the oil drop in test *c* has resulted in an alteration of the wetting characteristic of the solid. Both Oklahoma City and East Texas liquids gave this behavior, which is in direct contrast with that of the system shown in Fig. 16*f*. A difference is to be noted from Fig. 16*e*, where a zero angle was observed when iso-octane was brought into contact with a plate immersed in water. When water advances over a surface wet with iso-octane (*f*), an angle of 36° is obtained, indicating that the solid is still preferentially wet by water, although iso-octane does have an effect on the surface.

It is presumed that the crude oils contain certain polar compounds, which are responsible for their very striking behavior. Of extreme interest is the observation that although the crude oils do not displace water from a surface initially wet by water, the oils do alter the solid surface on contact, so that after a short time the water is incapable of displacing the oil from the solid surface. It seems reasonable to assume that this alteration of the solid surface was due to tenaciously adsorbed polar constituents from the crude oils.

H. F. Beardmore,* Tulsa, Okla.—In order to be brief, these remarks must be confined to a critical discussion of Dr. Katz' paper, and all comment on the many and predominating merits of the report must be omitted. However, one cannot overlook the excellent work of the engineers in recognizing the gravity drainage, in uncovering the difficulties of water-flooding and in compiling and evaluating a mass of data.

The fundamental conclusion of the paper is that 80 million barrels of oil is recoverable by secondary-recovery methods. This is qualified in three major ways: (1) that this 80 million barrels of oil is in excess of indicated primary recovery based on decline curves; (2) that this increased recovery will result from gas repressuring; and (3) that unit operation is required for part of this additional recovery.

Concerning the first qualification of the 80-million-barrel recovery above estimates from decline curves, the paper states: "The amazing feature of the Wilcox sand history has been the high recoveries of oil with continual upward revision of future production estimates." These upward revisions are currently occurring and will continue to occur. Additional recovery from new and deepened wells will also raise the estimates. These upward revisions of future production estimates will greatly reduce, and may even wipe out, the 80 million barrels now set up as secondary oil.

In the second qualification, gas injection is supposed to force oil down structure to producing wells but the paper points out also the effectiveness of gravity drainage and leaves no question but that it will continue. The paper

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then states: "Gas pressure differentials will force oil from one position to another, but it is not likely to move liquid from the well drained portion of the gas zone or cap." The logical conclusion from this is that natural gravity drainage will deplete the reservoir to a point where further depletion by gas drive will be impossible. There is the opportunity to recover a portion of the oil left in the drained zone by cycling and resaturating dry gas in this zone, but such recovery will be in the form of gasoline, which is not mentioned in the paper.

The third qualification is unitization. Its value to secondary recovery lies in a cooperative plan to dewater the oil zone now flooded. This appears to stretch the scope of secondary methods, but if this idea is to be considered, it could be currently applied by cooperative agreements in localized areas and not rate a secondary-recovery status.

Holding strictly to the paper, there appears to be: (1) primary recovery being revised upward that is tending to wipe out the indicated secondary oil; (2) a recovery by gravity drainage that greatly excels recovery by any known gas drive; and (3) unitization for water removal that is questionably labeled a secondary method. All this leads one to question the necessity for a secondary-recovery program. It is believed the data of the paper can logically be interpreted to show that present primary methods will practically and economically recover all the oil that is credited to the secondary-recovery program.

J. A. McCutchin,* Tulsa, Okla.—The brevity of Dr. Katz's paper does not permit him to do justice to the quantity or quality of work and study that has been spent upon the possibilities of secondary recovery for the Oklahoma City Wilcox sand by Dr. Katz and his associates.

One important consideration when a gas repressuring or recycling is contemplated is the increased recovery of gasoline, butane and propane. This important phase of repressuring was not covered in the paper. The Oklahoma City reservoir, with an extensive gas cap and partially saturated sand of high permeability, should respond very well to recycling dry gas. Field experiments indicate that dry gas can be injected and the same gas recovered in adjacent wells with a gasoline content of 2½ gal. per thousand cubic feet. Considering all factors pertinent to the subject, it appears that there is more certainty that a gas-recycling program to recover gasoline butane and propane is likely to be more profitable than repressuring to recover crude oil.

D. R. Knowlton,* Bartlesville, Okla.—Dr. Katz has stated concisely the problems and possibilities of engineering work and legislative problems that operators face in Oklahoma City. He has brought out the fact that this field differs from any other field in several aspects; namely, the sand is apparently oil-wet, the reservoir has a definite gas-oil contact or fluid level; there is less than 1 per cent connate water, and gravitational drainage has reduced the saturation in the gas cap greatly.

This field was very colorful in that it had many high-potential wells with large volumes of sand; several wild wells have been on fire; many wells have cut off their Christmas tree connections; difficulties have been encountered in controlling the flows from these wells and pumping oil from them, owing to the high sand content of the oil. This field has also promoted development of many new types of pumps, as well as improved beam pumps, to produce this oil from 6500 feet.

The groundwork for this paper by Dr. Katz was laid by the Oklahoma City Wilcox Secondary Recovery Association, which collected information on gas volumes, oil volumes, sand tops and sand bases, reservoir pressures, core and core analyses, connate-water content, fluid levels, water production, gas-injection programs, and many other phases of operation. As pointed out by Dr. Katz, even after all this information had been compiled, estimates of future primary production have been very unreliable in Oklahoma City.

Dr. Katz has discussed fluid levels in this paper, which indicates that zonal segregation between evolved gas, oil and water in this pool have been very definite. The experiment conducted by Dr. Katz on gravitational segregation of oil and evolved gases proved definitely that a few degrees variance in temperature on this setup would materially affect the rate of gravity drainage. From the data compiled from this experiment, he has concluded that natural gravity drainage has reduced the saturation in the gas cap to something like 20 per cent of the pore space, and in some cases as low as 1 per cent. The operators have tested this theory in the field by drilling some 50 new wells on the low side of the structure and getting some very good wells.

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In conducting the wettability experiments with Wilcox sand, and many other sands from over the state, Dr. Katz probably found the one vital fact that changed the operators' opinion from water-flooding to gas-recycle or gravity-drainage programs. From this report, Dr. Katz has shown definitely that if it were legally possible to unitize and operate a unit in Oklahoma City, gas-injection or gas-recycle programs combined with gravitational segregation would earn the companies many more millions of dollars from this reservoir than can be gained by competitive operations.

The Electrical Resistivity Log as an Aid in Determining Some Reservoir Characteristics

By G. E. Archie*

(Dallas Meeting, October 1941)

The usefulness of the electrical resistivity log in determining reservoir characteristics is governed largely by: (1) the accuracy with which the true resistivity of the formation can be determined; (2) the scope of detailed data concerning the relation of resistivity measurements to formation characteristics; (3) the available information concerning the conductivity of connate or formation waters; (4) the extent of geologic knowledge regarding probable changes in facies within given horizons, both vertically and laterally, particularly in relation to the resultant effect on the electrical properties of the reservoir. Simple examples are given in the following pages to illustrate the use of resistivity logs in the solution of some problems dealing with oil and gas reservoirs. From the available information, it is apparent that much care must be exercised in applying to more complicated cases the methods suggested. It should be remembered that the equations given are not precise and represent only approximate relationships. It is believed, however, that under favorable conditions their application falls within useful limits of accuracy.

Introduction

The electrical log has been used extensively in a qualitative way to correlate formations penetrated by the drill in the exploitation of oil and gas reservoirs and to provide some indication of reservoir content. However, its use in a quantitative way has been limited because of various factors that tend to obscure the significance of the electrical readings obtained. Some of these factors are the borehole size, the resistivity of the mud in the borehole, the effect of invasion of the mud filtrate into the formation, the relation of the recorded thickness of beds to electrode spacing, the heterogeneity of geologic formations, the salinity or conductivity of connate water, and, perhaps of greatest importance, the lack of data indicating the relationship of the resistivity of a formation *in situ* to its character and fluid content.

On the Gulf Coast it is found that the effects of the size of the borehole and the mud resistivity are generally of little importance, except when dealing with high formational resistivities or extremely low mud resistivities. Fortunately, little practical significance need be attached to the exact values of the higher resistivities recorded. Low mud resistivities are not common, but when this condition is encountered it may be corrected by replacing the mud column. With the present advanced knowledge of mud control, invasion of mud filtrate into sands can be minimized, thereby increasing the dependability of the electrical log. The effect of electrode spacing on the recorded thickness of a bed is often subject to compensation or can be sufficiently accounted for to provide an acceptable approximation of the true resistivity of the formation. As development of a field or area progressively enhances the knowledge of the lithologic section, the resistivity values of the electrical log take on greater significance, ultimately affording acceptable interpretations. The salinity, and

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therefore the conductivity, of the connate water associated with the various producing horizons may be determined with sufficient accuracy by the usual sampling procedure.

Determination of the significance of the resistivity of a producing formation as recorded by the electrical log appears, for the present at least, to rest largely with the application of empirical relationships established in the laboratory between certain of the physical properties of a reservoir rock and what may be termed a formation factor. It should be stressed at this point that numerous detailed laboratory studies of the physical properties of the formations in relation to the electrical measurements in question are essential to a reliable solution of the problems dealing with reservoir content. The purpose of this paper is to present some of these laboratory data and to suggest their application to quantitative studies of the electrical log. It is not intended to attempt to discuss individual resistivity curves and their application. The disturbing factors (borehole, bed thickness, and invasion) are discussed briefly only to indicate instances when they are not likely to affect the usefulness of the observed resistivity.

RESISTIVITY OF SANDS WHEN PORES ARE ENTIRELY FILLED WITH BRINE

A study of the resistivity of formations when all the pores are filled with water is of basic importance in the detection of oil or gas by the use of an electrical log. Unless this value is known, the added resistivity due to oil or gas in a formation cannot be determined.

The resistivities of a large number of brine-saturated cores from various sand formations were determined in the laboratory; the porosity of the samples ranged from 10 to 40 per cent. The salinity of the electrolyte filling the pores ranged from 20,000 to 100,000 milligrams of NaCl per liter. The following simple relation was found to exist for that range of porosities and salinities:

$$R_o = FR_w \qquad [1]$$

where R_o = resistivity of the sand when all the pores were filled with brine, R_w = resistivity of the brine, and F = a "formation resistivity factor."

In Figs. 1 and 2, F is plotted against the permeabilities and porosities, respectively, of the samples investigated. The data presented in Fig. 1 were obtained from consolidated sandstone cores in which the cementing medium consisted of various amounts of calcareous as well as siliceous materials. The cores had essentially the same permeability, parallel to and perpendicular to the bedding of the layers. All of the cores were from producing zones in the Gulf Coast region. Cores from the following fields were used: Southeast Premont, Tom Graham, Big Dome-Hardin, Magnet-Withers, and Sheridan, Texas; also La Pice, and Happytown, La. Fig. 2 presents similar data obtained from cores of a widely different sandstone; that is, one that had extremely low permeability values compared with those shown in Fig. 1 for corresponding porosities. These cores were from the Nacatoch sand in the Bellevue area, Louisiana.

From Figs. 1 and 2 it appears that the formation resistivity factor F is a function of the type and character of the formation, and varies, among other properties, with the porosity and permeability of the reservoir rock; many points depart from the average line shown, which represents a reasonable relationship. Therefore, individual determinations from any particular core sample may deviate considerably from the average. This is particularly true for the indicated relationship to permeability. Further, although the variation of F with porosity for the two groups of data taken from sands of widely different character is quite consistent, the effect of variations in permeability on this factor is not so evident. Naturally the two relationships could not be held to apply with equal rigor because of the well established fact that permeability does not bear the same relation to porosity in all sands. From close inspection of these data, and at the present stage of the investigation, it would appear reasonably accurate to accept the indicated relationship between the formation resistivity factor and porosity. Thus, knowing the porosity of the sand in question, a fair estimate may be made of the proper value to be assigned to F, based upon the indicated empirical relationship

$$F = \theta^{-m} \qquad [2]$$

or from Eq. 1,

$$R_o = R_w\theta^{-m} \qquad [3]$$

where θ is the porosity fraction of the sand and m is the slope of the line representing the relationship under discussion.

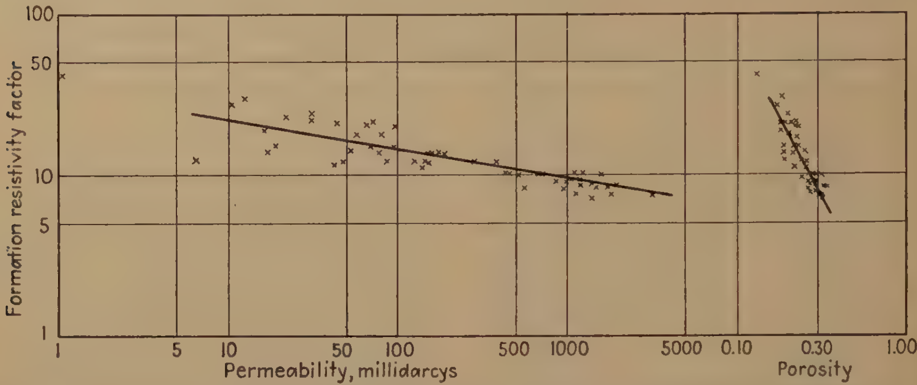

FIG. 1.—RELATION OF POROSITY AND PERMEABILITY TO FORMATION RESISTIVITY FACTOR FOR CONSOLIDATED SANDSTONE CORES OF THE GULF COAST.

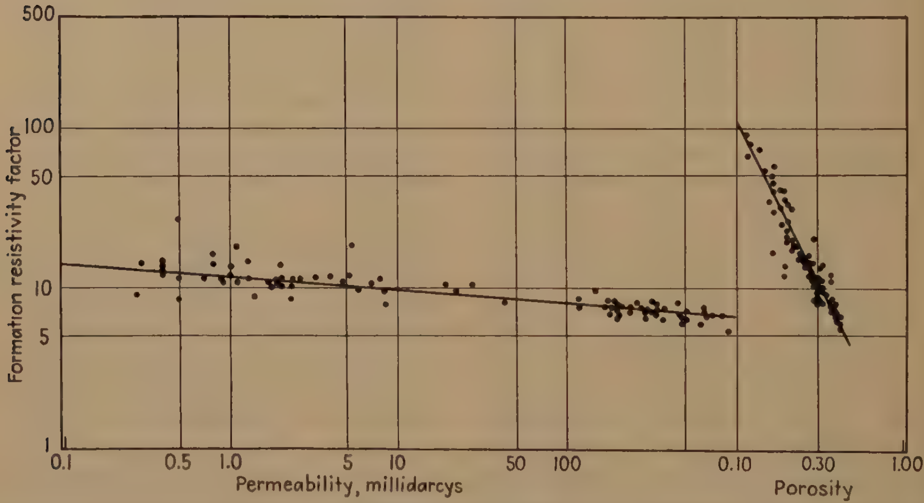

FIG. 2.—RELATION OF POROSITY AND PERMEABILITY TO FORMATION RESISTIVITY FACTOR, NACATOCH SAND, BELLEVUE, LA.

Permeabilities below 0.1 millidarcy not recorded.

From a study of many groups of data, m has been found to range between 1.8 and 2.0 for consolidated sandstones. For clean unconsolidated sands packed in the laboratory, the value of m appears to be about 1.3. It may be expected, then, that the loosely or partly consolidated sands of the Gulf Coast might have a value of m anywhere between 1.3 and 2.

RESISTIVITY OF FORMATIONS WHEN PORES ARE PARTLY FILLED WITH BRINE, THE REMAINING VOIDS BEING FILLED WITH OIL OR GAS

Various investigators—Martin,[1] Jakosky,[2] Wyckoff,[3] and Leverett[4]—have studied the variation in the resistivity of sands due to the percentage of water contained in the pores. This was done by displacing varying amounts of conducting water from the water-saturated sand with nonconducting fluid. Fig. 3 shows the relation which the various investigators found to exist between S (fraction of the voids filled with water) and R (the resulting resistivity of the sand) plotted on logarithmic coordinates. For water saturations down to about 0.15 or 0.20, the following approximate equation applies:

$$S = \left(\frac{R_o}{R}\right)^{\frac{1}{n}} \quad \text{or} \quad R = R_o S^{-n} \qquad [4]$$

For clean unconsolidated sand and for consolidated sands, the value of n appears to be close to 2, so an approximate relation can be written:

$$S = \sqrt{\frac{R_o}{R}} \qquad [5]$$

or from Eq. 1,

$$S = \sqrt{\frac{FR_w}{R}} \qquad [6]$$

Since in the laboratory extremely short intervals of time were allowed for the establishment of the equilibrium conditions compared with underground reservoirs, there is a possibility that the manner in which the oil or gas is distributed in the pores may be so different that these relations derived in the laboratory might not apply underground.

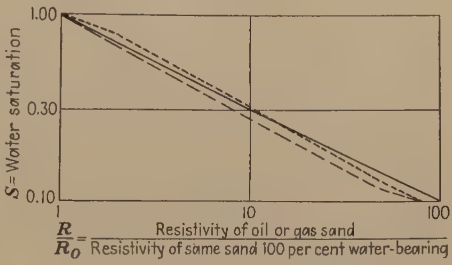

FIG. 3.—RELATION OF S TO $\frac{R}{R_o}$

Legend and Data

Curve	Investigator	Type Sand	Salinity of Water, Grams NaCl per Liter	Oil or Gas	Porosity Fraction
———	Wyckoff	Various		CO_2	Various
———	Leverett	Uncons.	8 approx.	Oil	0.40
– – –	Martin	Cores	130	Oil	0.20 and 0.45(?)
———	Jakosky	Friable	29 approx.	Oil	0.23

Considerable encouragement on this point is established, however. For example, Eq. 4 appears to hold even though gas or oil is the nonconducting phase. Each probably assumes a different distribution in the pores, yet the resulting resistivity is not appreciably changed. Also, no great change is found in the average relation between the formation resistivity factor and porosity for changes in types of consolidated sandstones. This indicates that even though the oil or gas underground may fill the pore space in a different manner from that in the short-time laboratory experiments, the relationship expressed by Eq. 4 should apply equally well underground.

BASIC RESISTIVITY VALUES TO BE OBTAINED IN ESTIMATING FLUID CONTENT OF A SAND

The foregoing discussion indicates that the basic values to be obtained are: (1) the resistivity of the sand in question underground (R), and (2) the resistivity of the same sand when its pores are entirely filled with connate water (R_o).

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[1] References are at the end of the paper.

The first value can be obtained from the electrical log when all factors can be properly weighed. The latter may also be obtained from the log when a log is available on the same horizon where it is entirely water-bearing. Of course, this is true only when the sand conditions, particularly porosity, are the same as at the point in question and when the salinity of the connate or formation water throughout the horizon is the same.

In a water-drive reservoir, or any reservoir where the connate water is in direct contact with the bottom or edge water, there should be no appreciable difference in the salinities through the horizon, at least within the limits set forth for the operation of Eqs. 1 and 4; that is, when the salinity of the connate water is over 20,000 mg. NaCl per liter and the connate water is over 0.15. In depletion-type reservoirs, or when connate water is not in direct contact with bottom or edge water, special means may have to be devised to ascertain the salinity of the connate water.

When it is not possible to obtain R_o in the manner described above, the value can be approximated from Eq. 3, θ and m having been determined by core analyses and R_w by regular analyses.

Calculation of Connate Water, Porosity and Salinity of Formation Water from the Electrical Log

The resistivity scale used by the electrical logging companies is calculated assuming the electrodes to be points in a homogeneous bed.[5] Therefore, the values recorded must be corrected for the presence of the borehole, thickness of the layers in relation to the electrode spacing, and any other condition different from the ideal assumptions used in calculating the scale.

Consider a borehole penetrating a large homogeneous layer, in which case the electrode spacing is small in comparison with the thickness of the layer. If the resistivity of the mud in the hole is the same as the resistivity of the layer, there will be, of course, no correction for the effect of the borehole. If the resistivity of the mud differs from the resistivity of the layer, there will be a correction. Table 1 shows approximately how the presence of the borehole changes the observed resistivity for various conditions. The third curve, or long normal, of the Gulf Coast is considered because this arrangement of electrodes gives very nearly a symmetrical picture on passing a resistive layer and has sufficient penetration in most instances to be little affected by invasion when the filtrate properties of the mud are suitable.

Table 1.—*Effect of Borehole on Infinitely Large Homogeneous Formation*

True Resistivity of Formation, Meter-ohms	Observed Resistivity on Electric Log			
	In an 8-in. Borehole		In a 15-in. Borehole	
	Resistivity of Mud in Hole (at Bottom-hole Temperature) of		Resistivity of Mud in Hole (at Bottom-hole Temperature) of	
	0.5 Meter-ohms	1.5 Meter-ohms	0.5 Meter-ohms	1.5 Meter-ohms
0.5	0.5	0.5	0.5	0.5
1	1	1	1	1
5	6	5	5	5
10	12	11	11	11
50	65	65	50	55

The values in Table 1 have been calculated assuming a point potential "pick-up" electrode 3 ft. away from a point source of current, other electrodes assumed to be at infinity, and it has been found that the table checks reasonably well with field observations. Checks were made by: (1) measuring the resistivity of shale and other cores whose fluid content does not change during the coring operation and extraction from the well; (2) measuring the resistivity of porous cores from water-bearing formations after these cores were resaturated with the original formation water. Adjustment due to temperature difference, of course, is necessary before the laboratory measurement is compared with the field measurement.

TABLE 2.—*Effect of Formation Thickness, No Borehole Present*

True Resistivity	Observed Resistivity		
Layer between Large Shale Bodies Having Resistivity of 1.0 Meter-ohms	Thickness of Layer		
	24 Ft.	16 Ft.	8 Ft.
1	1	1	1
5	5	5	3
10	10	9	6
20	20	19	11

The correction at the higher resistivities appears to be appreciable. However, in the Gulf Coast when the value of R_o is low the correction is not so important. For example, assume a friable oil sand whose true resistivity is 50 meter-ohms and whose resistivity when entirely water-bearing is 0.50 meter-ohms; the connate water would occupy about 0.10 of the pore volume (Eq. 5). However, if the observed value on the log, 65 meter-ohms, were used without correcting for the borehole, the connate water would be calculated to occupy 0.09 of the pore volume. Therefore, although the effect of the borehole size and mud resistivity on the observed resistivity readings may be appreciable, the resultant effect on the calculated connate-water content of the sand is not important.

When the thickness of the formation is very large in comparison with the electrode spacing, there will, of course, be no correction to make for the thickness of the layer. However, when the thickness of the formation approaches the electrode spacing, the observed resistivity may be very different from the true value. Table 2 shows approximately what the third curve (long normal) of the Gulf Coast would read for certain bed thicknesses and resistivities. It is assumed that large shale bodies are present above and below the beds, at the same time neglecting the presence of the borehole and again assuming point electrodes.

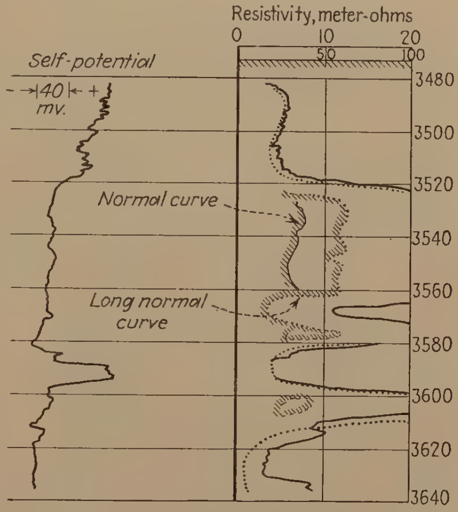

FIG. 4.—ELECTRICAL LOG OF AN EAST TEXAS WELL.

Diameter of hole, 7⅞ in.; mud resistivity, 3.4 at 85°F.; bottom-hole temperature, approximately 135°F.

Tables 1 and 2 assume ideal conditions, so if the sand is not uniform, or if invasion affects the third curve, the observed resistivity values may deviate farther from the true value. The magnitude of the influencing factors, of course, will limit the usefulness of the observed resistivity value recorded on the log. Invasion of the mud filtrate is probably the most serious factor; however, as previously mentioned, it can often be controlled by conditioning the mud flush for low filtrate loss.

Fig. 4 shows a log of an East Texas well. The observed resistivity on the long normal curve for the interval 3530 to 3560 ft. is 62 meter-ohms, or, from Table 1, approximately 50 meter-ohms after correcting for the borehole. In this instance the mud resistivity at the bottom-hole temperature of 135°F. is approximately 2.2 meter-ohms.

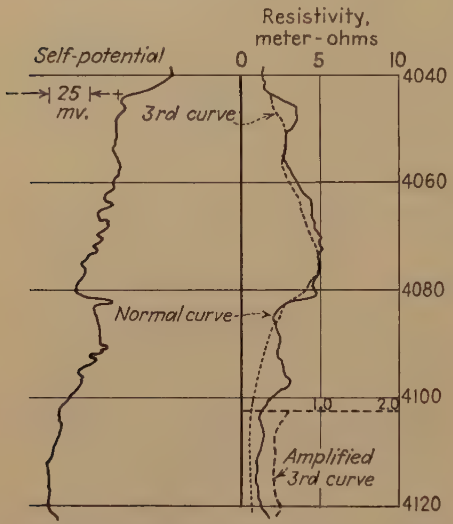

Fig. 5.—Electrical log of a sand in East White Point field, Texas.

Diameter of hole, 7⅞ in.; mud resistivity, 1.7 at 80°F.; bottom-hole temperature, 138°F.

The interval is thick enough so that there should be no appreciable effect due to electrode spacing. The formation is more or less a clean friable sandstone, so Eq. 5 can be used to approximate the connate-water content. The formation resistivity factor for this sand is approximately 15, using Eq. 2 where $\theta = 0.25$ and $m = 1.8$. The resistivity of the formation water by actual measurement is 0.075 meter-ohms at a bottom-hole temperature of 135°F. Therefore, from Eq. 1, R_o for this sand is $15 \times 0.075 = 1.1$ meter-ohms. This value checks reasonably well with the value recorded at 3623 to 3638 ft. on this log as well as on the many logs from this pool where the Woodbine sand is water-bearing; i.e., 0.9 to 1.5 meter-ohms. The close check obtained between the calculated and recorded resistivity of the water sand indicates that invasion is not seriously affecting the third curve. Solving Eq. 5, the connate water of the zone 3530 to 3560 ft. occupies approximately $\sqrt{\frac{1.1}{50}} = 0.15$ of the pore volume. The accepted value assigned for the connate-water content of the East Texas reservoir is 17 per cent.

An electrical log of a sand in the East White Point field, Texas, is shown in Fig. 5. The observed resistivity at 4075 ft. is approximately 5 meter-ohms. The value of F for this sand by laboratory determination is 6. The sand is loosely consolidated, having 32 per cent porosity average. The resistivity of the formation water by direct measurement is 0.063 meter-ohms at the bottom-hole temperature of 138°F. Therefore, $R_o = 6 \times 0.063$ or 0.38 meter-ohms. This checks well with the value obtained by the electrical log between the depths of 4100 and 4120 ft., which is 0.40 (see amplified third curve). Therefore, invasion probably is not seriously affecting the third curve. From Tables 1 and 2 it appears that the borehole and electrode spacing do not seriously affect the observed resistivity at 4075 ft. The connate water is approximately $\sqrt{\frac{0.38}{5.0}}$, or 0.27.

Other uses of the empirical relations may have occurred to the reader. One would be the possibility of approximating the maximum resistivity that the invaded zone could reach (when formation water has a greater salinity than borehole mud) by Eq. 1, where R_w would now be the resistivity of the mud filtrate at the temperature of the formation and F the resistivity factor of the formation near the borehole. By knowing the maximum value of resistivity that the invaded zone could reach, the limits of usefulness of the log could be better judged. For example, assume that a porous sand having an F factor of less than 15 was under consideration. If the mud filtrate resistivity were 0.5 meter-ohms, the resistivity of the invaded zone, if completely flushed, would be $15 \times 0.5 = 7.5$. Thus the observed resistivity values of this sand up to approximately 7.5 meter-ohms could be due to invasion.

ACKNOWLEDGMENT

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DISCUSSION

(*H. F. Beardmore presiding*)

S. W. WILCOX,* Tulsa, Okla.—This paper recalls some of my own observations on the correlation of the electrical resistance of earth materials with their other physical properties. While Geophysical Engineer for the Department of Highways, of the State of Minnesota, from 1933 until 1936, I was primarily engaged in conducting earth-resistivity surveys prospecting for and exploring sand and gravel deposits. This work was done by two field parties using equipment of the Gish-Rooney type, and was carried out in every part of the state, both winter and summer.

In brief, when a sand or gravel prospect was discovered, in any way, it was detailed by the resistivity survey to outline its extent and to locate test holes for field and laboratory sample analysis. This survey consisted of a grid of "steptraverses" of one or more electrode separations, and for each an "iso-ohm," or equal resistance contour plan map, was drawn.

Several thousand earth-resistivity readings were taken over more than one hundred prospects. In some instances the test pitting was started before the completion of electrical survey and their findings were soon available for checking any suspected correlation theory and confirming what subsurface factors were being measured and how effectively.

From accepted earth-resistivity theory, it follows that within a definite sphere surrounding the electrodes the apparent resistance measurement is uniquely determined from the specific resistance and position of each and all of the particles making up the sphere. Any rational interpretation of these apparent resistance measurements is possible only for the simplest combinations of particles and their specific resistances. Fortunately, soils, subsoils and subsurface rocks, with their embodied fluids and gases, vary greatly in this property among themselves. For example, clay appears to have an average specific resistance of approximately 50 to 150 foot-ohms, whereas for sand and gravel the specific resistance is roughly from 2000 to 5000 foot-ohms. The important feature is the great absolute differences in resistance, consequently a resistance profile across a buried lens of sand or gravel surrounded by clay produces a striking response.

In spite of the amount of control available and the freedom for selecting various electrode intervals, no reliable quantitative predictions could be made that were not related to boundary surfaces. The probable depth to the first discontinuity—namely, the clay-sand contact—could be determined fairly accurately if the thickness of the sand body was considerable. When the depth to the sand was known from independent data, or could be assumed to be constant, it was possible to predict its thickness. If both were known, a good guess might be made regarding the depth to the water table; and, in addition, if all these were known, a surmise could be made about the quality of the sand; i.e., whether it contained organic material or was weathered. Perhaps if the degrees of control were sufficient the porosity of the sand, its grain size, or even its temperature might be predicted.

I observed that few of these variables, even the ones that generally contribute to the bulk of the readings, could be quantitatively separated without additional independent data; therefore my interpretation was necessarily empirical and based on experience. Fortunately, in sand and gravel prospecting the economically most important factors contribute their effects in the same direction. A high apparent resistance indicates either a thin body of highly resistant gravel near the surface, or a thicker one overlain with more clay stripping. Clean gravel is more resistant than weathered, and hard gravel more so than soft.

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* Seismograph Service Corporation.

In practical terms, I found that an apparent resistance reading of 500 foot-ohms for a 20-ft. electrode separation recorded over ground or glacial moraines of southern Minnesota reliably suggested a deposit of sand or gravel worth further investigation. As a matter of record, prospecting in the part of the state where these materials are very scarce, less than 3 per cent of the test holes located on the geophysical information failed to yield granular materials of commercial quality and quantity for at least highway subgrade treatment. Varying the electrode interval gave additional confirmation as to the thickness of the deposit and very little else.

In connection with our field work, we made extensive laboratory studies, attempting to work out the relation between the moisture content of sand and gravel and its specific resistance. These apparently simple experiments were not of much help in clearing up my field interpretations. Several variables were very hard to control in the laboratory.

The analogy between this type of earth-resistivity mapping and electrologging is close. The first measures electrical impedance along a surface generally parallel to the bedding planes; the latter, up a borehole more or less perpendicular to them. The same general limitations and possibilities appear to be common to both methods. Obviously, controls for checking are easier to obtain for plan mapping than for well logging within the depth of effective penetration.

My interpretation problems appeared to be essentially similar to those of electrical well logging where the operator, after observing the character of the resistance and the self-potential curves, tells his client whether pipe should be set. The accuracy of his prediction is based largely on experience and not on slide-rule calculations.

Mr. Archie's paper suggests an experimental attack for expanding and improving the interpretation technique of electrical well logging. Any contribution of this nature that increases its effectiveness is of great value to the petroleum industry. I offer my own experiences and observations to emphasize that he has tackled a difficult research problem and wish him luck.

Dr. A. G. Loomis,* Emeryville, Calif.—In the laboratory, we take into account the variations in measured resistivities of sands and tap water by finding out the cause of the variations in resistivity. That is, if the tap water itself varied from day to day, its electrolyte content must vary from day to day and chemical analysis would indicate the change. If sands did not give consistent resistivity readings, the character of the sands (in other words, the formation resistivity factor) probably changed or the kind and amount of water contained in the sand must have varied.

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* Shell Development Co.

Field Application of Core Analysis and Depth-pressure Methods to the Determination of Mean Effective Sand Permeability

By N. van Wingen,* Member A.I.M.E.

(Los Angeles Meeting, October 1941)

Effective sand permeabilities can be ascertained from core analysis if the laboratory data are compensated to allow for the presence of connate or residual water. Such adjustments can be made by applying empirically derived correction factors.

Effective sand permeabilities can be estimated also from analytical studies of field depth-pressure measurements. In one method the time rate of pressure build-up after a well is shut in from steady-state flow is required, and in the other the direct measurement of a steady-state rate of flow and the corresponding equilibrium pressure.

The results of the investigation discussed in this paper demonstrate that these methods for determining mean effective sand permeabilities can be correlated.

Introduction

In recent years many investigators have demonstrated the practical value of an accurate knowledge of the physical and dynamical characteristics of reservoir sands containing oil and gas. Of these factors, which serve to completely define a porous medium as a container or carrier of fluids, the dynamical characteristics are of particular interest to the production engineer because they afford a direct measure of the rate at which the oil or gas content of a reservoir will become available. The constant that defines dynamically the porous medium as the carrier of a homogeneous fluid in viscous motion is the "permeability."

Core-analysis Method

The generally accepted practice in compiling permeability data has been to analyze in the laboratory core samples taken in the course of drilling through the productive horizon, and to obtain the mean measure of the productive ability or permeability for the interval open to production by graphical integration of the permeability profile.

An average permeability ascertained in this manner, however, is useful to the production engineer only for comparisons of wells drilled in the same horizon, as permeabilities determined in the laboratory are measures of only the ability of a porous medium to transmit a single fluid. As a result of many investigations, it has been shown, however, that under actual reservoir conditions water is coexistent with the petroleum and that its presence greatly reduces the permeability of the sand to oil. Empirical relationships showing the effect of the presence of any immiscible fluid A (such as water) in a porous medium on the permeability of the medium to a fluid B (such as oil) have been established separately by Hassler,[1] Dunlap,[2] and the writer (Fig. 1),[3] so that the average specific or dry-core permeability as determined in the laboratory can be corrected to give the true measure of the ability of the horizon penetrated to transmit oil, provided the percentage of pore space occupied by connate water is known accurately.

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* Production Engineer, Richfield Oil Corporation, Taft, California.

[1] References are at the end of the paper.

Depth-pressure Methods

Another manner in which mean effective sand permeabilities can be obtained is by means of an analytical study of field depth-pressure measurements. Permeabilities determined from actual reservoir data inherently reflect the obstructional effect of the connate water, so that the results of such an analysis will give directly the mean effective permeability. Actually, as the basic pressure measurements are taken within the well bore, resistances to flow caused by the liner and sand face will be included also, but the latter effects can generally be considered small compared with the sand resistance in properly completed producers.

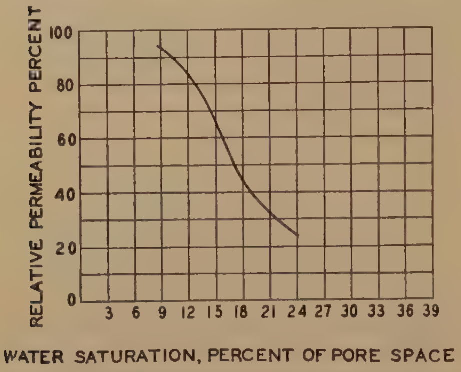

Fig. 1.—Influence of water saturation on permeability of sands to oil.
From paper by N. van Wingen.[3]

As any study pertaining to the flow of fluids into an actual well involves either a two-dimensional or three-dimensional flow system, the simple statement of Darcy's law, which is used when permeabilities are calculated from the one-dimensional laboratory tests, must be generalized to be applicable to the more complex flow problem.[4] Such a general statement of Darcy's principle becomes in effect an empirically derived macroscopic equivalent of the Stokes-Navier equation of classical hydrodynamics. As Darcy's law strictly applies only to the wholly viscous flow of homogeneous or single-phase fluids, a restriction to application may be imposed by the phase behavior of the reservoir fluid.

Provided the limitation in regard to the phase behavior of the reservoir fluid can be satisfied, however, Muskat[5] has shown that

$$Q = C\Delta P \qquad [1]$$

in which Q = volumetric rate of fluid entry into the well,
C = well characteristic,
ΔP = pressure differential inducing flow.

The well characteristic is a constant for any given system and is a function of the dimensions of the system and the properties of the sand and fluid.

A simple flow system, yet one that is representative of many actual field conditions, is that in which the flow is of a two-dimensional character, as in a radial flow system. Often flow into a well may be assumed to be radial if the productive horizon is completely penetrated, and Muskat[5] has shown that for such a system

$$C = 2\pi Kh/\mu \log_e \frac{r_e}{r_w} \qquad [2]$$

in which K = mean effective permeability,
h = sand thickness,
μ = absolute fluid viscosity,
r_e = drainage radius,
r_w = well-bore radius.

Field measurements to determine Q and ΔP in Eq. 1 in order to obtain the value of C may be taken in two different ways. One method, as proposed by Muskat,[5] requires that several depth-pressure measurements be made, to establish the time-rate of pressure build-up as a well is shut in from a steady-state condition of single liquid-phase flow. The latter limitation is imposed not only because it is a prerequisite for a strict application of Darcy's law, but also because the analytical treatment to follow will not strictly apply to cases in which free gas is present, because of the variation in the effective permeability of the sand as the gas is compressed by the increase in pressure.

The most practical analytical presentation of the phenomenon of pressure rise is obtained when it is assumed that the shutting in process will be one in which the fluid head simply rises from its initial flowing value until equilibrium is reached and that the back pressure upon the sand will at all times be a function of this fluid rise, or

$$Q = A\,\frac{\partial H}{\partial t} = f(p)$$

For these conditions it can be shown that

$$\gamma_o gCt/A = \log_e \frac{P_e - P}{P_e - P_i} \qquad [3]$$

in which γ_o = density of fluid,
g = acceleration of gravity,
C = well characteristic as shown by Eq. 2,
t = time after shut in, in seconds,
A = effective cross-sectional area of the well bore,
P_e = reservoir pressure,
P_i = initial steady-state flowing pressure,
p = pressure at any instant t.

For simplicity of use, Eq. 3 can be written in the form:

$$\frac{P_e - P}{P_e - P_i} = e^{-Bt} \qquad [4]$$

in which

$$B = 2\pi Kh\gamma_o g/\mu A \log_e \frac{r_e}{r_w} \qquad [5]$$

If for any particular set of well data a plot of Eq. 4 on semilogarithmic paper is a straight line, thus confirming the assumption of "dead" liquid flow upon which the derivation is based, the slope of this curve will then give the constant B and hence a means of determining the mean effective sand permeability K.

The other method, proposed by Wyckoff and co-workers,[6] involves the direct measurement of a steady-state rate of flow, Q, and the corresponding equilibrium pressure, P_w, at the sand face. In this event the fundamental Eq. 1 can be written as:

$$Q = C(P_e - P_w) \qquad [6]$$

This equation thus affords an easy means of determining the value of the well characteristic C directly from simple field measurements, and in turn the mean effective sand permeability by suitable substitution in Eq. 2.[7]

If the various elements in Eq. 6 are expressed in terms of the conventional field engineering units, barrels per day and pounds per square inch, the well-characteristic constant will be numerically equal to the well-known field measure of productive ability, the productivity index.[8]

This second method thus affords a means of obtaining mean effective permeability data directly from productivity indices, and thus makes these data easily available for wells that were not cored, provided well and reservoir characteristics are such that the essential premises upon which the treatment is based are satisfied.

The foregoing discussion indicates that the analytical treatment for obtaining mean effective sand permeabilities from basic field depth-pressure measurements is not complicated. Some difficulty is experienced, however, in keeping actual quantitative work in terms of consistent dimensional units, because of the variety of ways in which the various component factors commonly are measured. Foremost among these is the unit denoting permeability. From a consideration of the theory of dimensions,[9] it can be shown that the dimensions of permeability are those of an area. Hence, for a systematic analysis by a gravitation feet-pounds-seconds or c.g.s. system the permeability will be obtained in terms of either square feet or square centimeters, respectively, instead of the more commonly used Darcy unit. The Darcy unit requires that pressures be expressed in terms of atmospheres, while the other elements would follow the metric system. This divergence from a consistent system of measurements was deliberately chosen for the sake of obtaining convenient numerical values for the permeabilities of naturally occurring porous media.

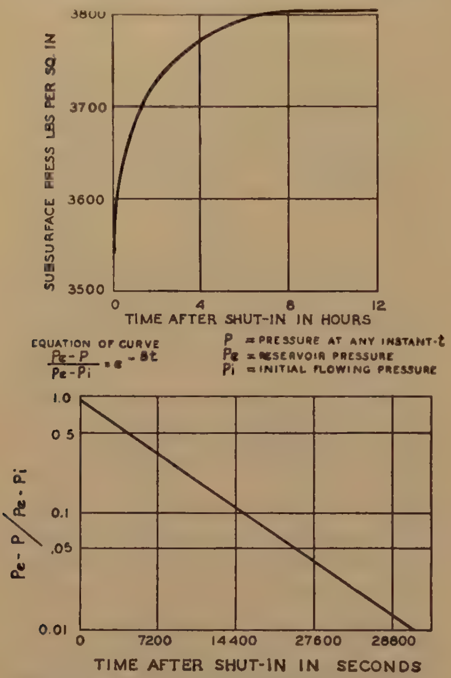

FIG. 2.—BASIC DEPTH-PRESSURE DATA TO DETERMINE MEAN EFFECTIVE SAND PERMEABILITY FROM RATE OF PRESSURE BUILD-UP, WELL A.

Consistent units of permeability can readily be converted to millidarcys, however, by the application of the following conversion factors:

$$\overline{\text{Ft.}}^2 \times 9.416 \times 10^{13} = \text{millidarcys}$$
$$\overline{\text{Cm.}}^2 \times 1.013 \times 10^9 = \text{millidarcys}$$

Other elements whose units require detailed attention are the viscosity, which for this treatment is the absolute viscosity or lb.-sec. per sq. ft. for the engineering or centipoise units for the metric system of measurement, and the density, which is to be expressed as slug or metric mass units per unit volume.

FIELD APPLICATION

The foregoing pages outline briefly three methods for determining mean effective sand permeabilities. For the purpose of comparing numerical results obtained by these respective procedures, the methods were applied to two wells in a San Joaquin Valley deep field in Kern County, California. The wells were selected for completeness of core-analysis data and degree of zonal penetration in a field for which phase-behavior data had shown that the reservoir liquid was undersaturated at the lowest flowing subsurface pressures encountered in the field tests, thus meeting the essential requirements for the applicability of the methods.

An example of basic data on pressure build-up is shown for one of the wells in Fig. 2. From such rate of pressure increase, productivity index, and core-analysis data the actual mean effective sand-permeability values of Table 1 were obtained.

The satisfactory relative agreements indicated for the results as obtained by the various methods would seem to offer valid proof that even the most simplified analytical treatment of a reservoir problem can lead to results of commensurate accuracy, provided the field application is confined to areas that meet at least the essential premises upon which such treatment is based.

TABLE 1.—*Actual Mean Effective Sand-permeability Values*
MILLIDARCYS

Mean Effective Permeability	Well A	Well B
Estimated from core-analysis data corrected for effect of connate water (method I)	3.20	5.25
Based on rate of pressure build-up (method II)	2.04	3.77
Based on productivity index (method III)	2.18	3.92

The adaptability and soundness of an analytical approach to a problem as inherently complex as that involving the movement of fluids through the porous media of actual oil or gas reservoirs is thus demonstrated.

ACKNOWLEDGMENTS

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Core Analysis—an Aid to Increasing the Recovery of Oil

By James A. Lewis,* Member A.I.M.E.

(Los Angeles Meeting, October 1940)

It is the purpose of this paper to show the importance of sand characteristics, when combined with other physical data, in evaluating production obtained by secondary recovery operations, and to indicate the benefits to be gained from the application of these principles to primary production.

Introduction

During the past 10 years there has been a growing interest within the industry regarding the movement of fluids through oil reservoirs. A number of research projects have been directed toward the development of the physical laws governing this movement. In the period 1933 to the present, correlations between laboratory analysis of cores, reservoir fluids and well performance have been established and have been applied to successful secondary water-flooding recovery operations; and to the completion, production, reconditioning and evaluation of wells in new fields.

The application of these data to waterflooding, either natural or artificial, is comparatively new, but the principles involved were set forth in 1880 by John F. Carll,[1] who said:

> *The flooding of an oil district is generally viewed as a great calamity*, yet it may be questioned whether a larger amount of oil cannot be drawn from the rocks in that way than by any other, for it is certain that all the oil cannot be drawn from the reservoir without admission of something to take its place.
>
> If one company owned all of the wells drawing upon a pool, and had accurate records of the depth and characteristics of the oil producing stratum in each well, it is quite possible that some system might be devised by which water could be let down through certain shafts, and thus the rocks be completely voided of oil and left full of water. As it is, however, no systematized plan of action can be adopted. The careless handling of one well, by which water is let down to the oil rock, may spoil several others belonging to different parties. A clashing of interests at once arises and is likely to result in disaster to the whole district.
>
> *In judging of the probable effects of the introduction of water* into any particular oil district several things are to be considered.
>
> (1st) *The time of flooding*—whether early in the progress of development, while yet a large percentage of oil remains unexhausted or at a later period after the supply has suffered from long continued depletion. (2nd) *The structure of the rock*—whether regular and homogeneous throughout, or composed of fine sand interbedding connected and irregular layers of gravel, sometimes lying near the top and at others near the bottom. (3rd) *The shape of the area being flooded.* (4th) The position of the *point at which water is admitted*, in relation to the location of the surrounding wells still pumping oil. (5th) *The height* (which governs the pressure) *of the column of water obtaining admittance.* (6th) *The duration of the water supply.*

Although we may take exception to part of Carll's reasoning, particularly "and thus the rocks be completely voided of oil and left full of water," we must give him credit for pointing out the increased effectiveness of water encroachment in displacing oil from a sand and for his recording six of the present seven considerations necessary for evaluation of production of oil by water

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* Vice-President, Core Laboratories, Inc., Dallas, Texas.

[1] References are at the end of the paper.

drive. The seventh covers the reservoir fluid characteristics and their distribution.

Carll's contributions to the industry during the first few years of its life laid the foundation for our present petroleum engineering work. We have been negligent in recognizing his statement of principles and also in applying them.

CORRELATION OF SAND AND PRODUCING CHARACTERISTICS

(*Secondary Recovery Operations*)

The production of gas, oil and water from a well takes place only after flow of these fluids through permeable reservoir formations. The analysis of cores has developed to a point where it is possible through accurate and complete analysis of contaminated or uncontaminated cores, for permeability, porosity, oil and water content and combination of these data, to predict with a high degree of accuracy the type of fluid production that will result by exposing a given cored interval to a pressure lower than that present in the formation. Having obtained oil production, the problem resolves itself into one of evaluating the formation in terms of rate and ultimate production of oil. The following discussion presupposes that the formation is oil productive and that accepted core-analysis methods[2–4] were combined with connate water[5–7] and residual oil saturation data[8] in computations for recovery. These determinations were correlated in accordance with principles published by Muskat and Wyckoff[9,10] and were found to be applicable in the water-flooding area of Bradford, Pennsylvania.

By 1934 it was proved to the satisfaction of the writer that, within a given field, the permeability of the sand to a homogeneous fluid and the thickness of permeable sand were the significant variables to be evaluated in order that the rate of intake to a given well might be determined. Since the production of oil by water drive is accomplished primarily through the displacement of the oil by an equivalent volume of water, permeability carried even greater significance, for it indicated the appropriate spacing program and oil recovery that would be obtained within a given time for preassigned economic conditions. In addition, the distribution and variation of permeability values within each sand section, combined with viscosity of the reservoir fluids, produced a workable basis for determining the limit of permeability values that would be flooded at the time the economic water-oil ratio was reached.

Fig. 1 relates the practical applications of permeability to oil-production characteristics.* Coregraph 1 and curve 1, respectively, show a highly variable permeability profile and the resultant oil-production curve from a Bradford area under flood. In Coregraph 2 and curve 2 similar data are shown from an area that is typical of average permeability variations for Bradford sand. Coregraph 3 and curve 3 record the permeability profile and rate of intake to a low-permeability sand development. Confirming a preceding statement, it is apparent from the foregoing curves that with factors of recovery, feet of permeable sand, well spacing, injection pressure, and viscosity of reservoir fluids remaining constant, permeability is a most important variable in evaluating anticipated profit or loss from a given operation. This should not be construed, however, to mean that other physical data are not important; rather that within a given field the other factors can and should be evaluated and accounted for before the operating program for the area under consideration is outlined. Thus it becomes possible to anticipate the yield per five-spot or per acre at any given time and to know as well the sand thickness that has been depleted. Not one of these

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* The specific productive capacity in each area has been satisfactorily correlated in accordance with the positive displacement principle described later.

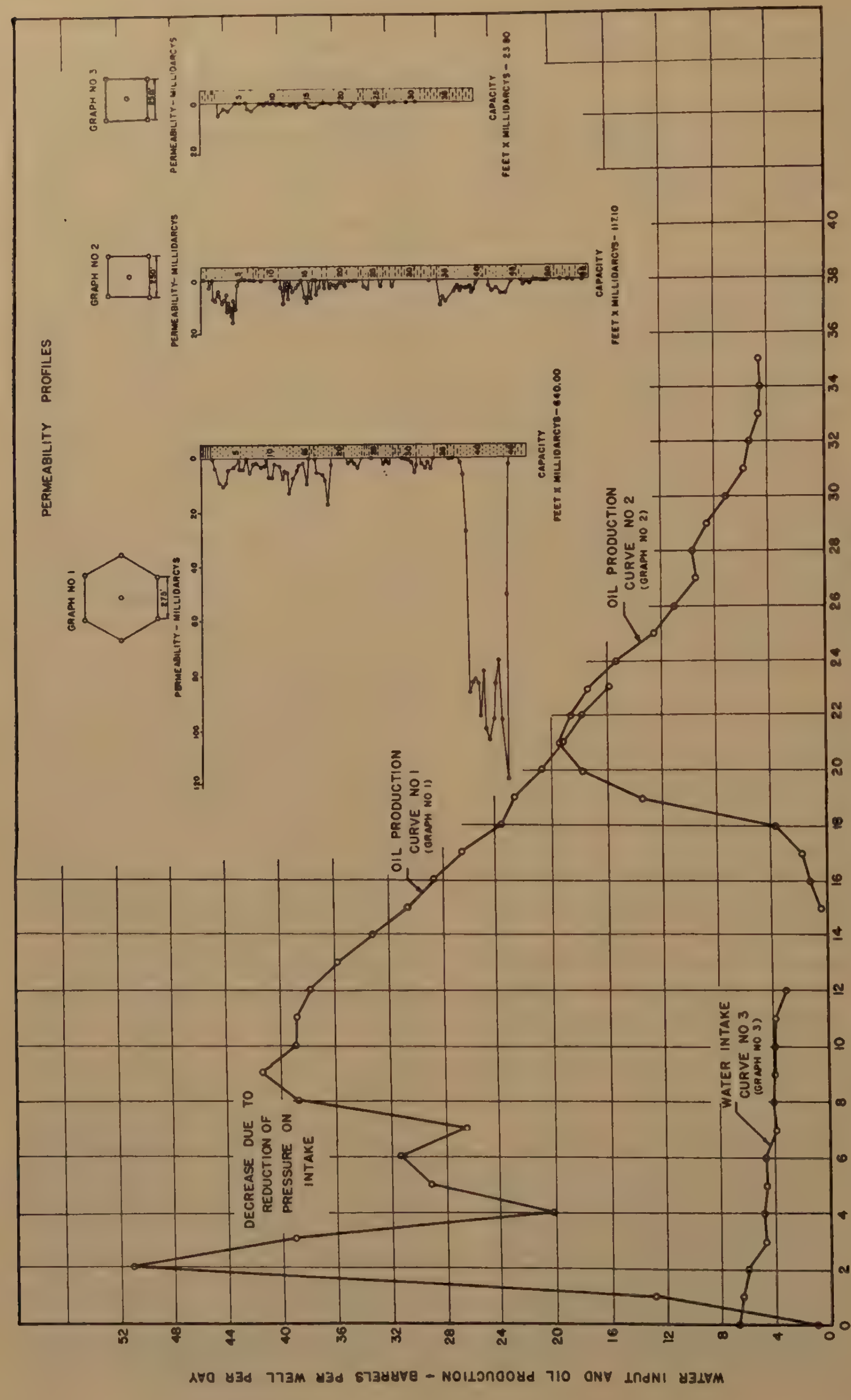

FIG. 1.—OIL-PRODUCTION AND WATER-INPUT CHARACTERISTICS OF THREE ARTIFICAL WATER-FLOOD AREAS.

physical facts should be omitted in the evaluation. Accurate knowledge is essential to profitable operation and to the disclosure of undesirable areas.

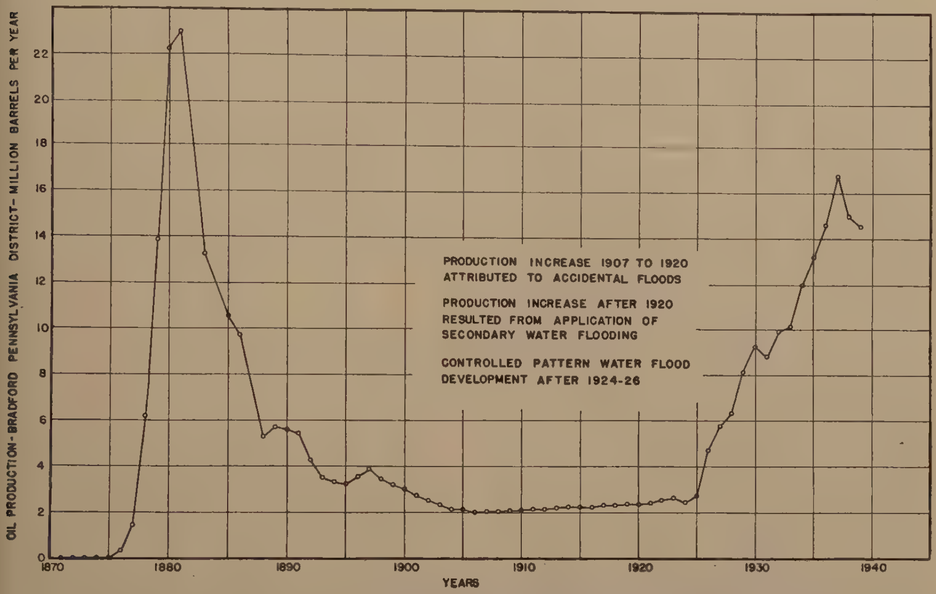

FIG. 2.—OIL PRODUCTION, BRADFORD DISTRICT, PENNSYLVANIA, MILLION BARRELS PER YEAR. Production data through courtesy of Mr. R. M. Haskell and Mr. R. T. Zook.

Rate of intake and rate of recovery have been calculated from core analyses for many different flood operations and, when compared with the actual values from operating records, have shown good agreement. A specific example is from the area represented by Coregraph 1 and curve 1 of Fig. 1, wherein, quoting from the report dated June 25, 1936, of which this profile was a part: "A total recovery of 6740 bbl. of oil (per acre) is expected in 6.5 years, 2150 of which will have been produced in one year's time from the bottom sand section." Inspection of the production records from this development shows that during the year beginning July 1, 1936 (the date of starting water injection), 1940 bbl. of oil per acre had been recovered as compared with the indicated 2150. The actual injection pressure used during this period was slightly lower than the value used in making the calculations and thus accounts for much of the difference between prediction and performance. The present rate of production indicates that for the conditions of pressure used in the operation, the ultimate yield as calculated will be obtained.

The extent to which water-flooding has been applied in the 84,000-acre Bradford field is evidenced by the production curve of Fig. 2. Systematic water-flooding came into prominence in 1928 and has continued to the present time. Higher injection pressures have been used in the more recent developments.

MECHANICS OF WATER-DRIVE PRODUCTION

The conclusion from these data is that the production of oil from an artificial water-drive operation, at economic rates of production, takes place by the mechanism of positive displacement of the oil saturation that is present in excess of the final residual equilibrium oil saturation for the system, substantially in accordance with the permeability of the sand to homogeneous fluid flow. Continued injection by maintenance of pressure, after water is produced from the more permeable strata, results in the displacement of oil from the less permeable zones (in agreement with the positive displacement principle), effecting recovery from sands of decreasing permeability until the ratio of water to oil production becomes uneconomical. In natural water-drive fields, it is indicated that a similar mechanism is operative.

Obtaining Reservoir Characteristics

Formation characteristics in Bradford, as well as in the Nowata area of northeastern Oklahoma, where artificial water-flooding has been initiated in more recent years, were obtained only by drilling new wells to obtain cores for analysis. The original development in these areas took place prior to the introduction of coring or core analysis. Similar history necessarily will need to be repeated as previously uncored territories are investigated. With more production coming from greater depths, the use of such a practice to obtain knowledge of the formation may not be justified in the future. This information should be obtained when wells are drilled, for then the results are of greatest application and value, and are obtainable at minimum expense.

Cores from prospective secondary recovery areas can be obtained without contamination by fluids extraneous to the formation, thus simplifying interpretation for the type and amount of probable production. It is now equally possible, as the result of recent work, to compute from core analyses the normal connate-water content of flushed cores from reservoirs under normal hydrostatic pressure to within 10 or 15 per cent deviation from values obtained from tracer or oil-base mud cores. These comparisons have been made in sands ranging in permeability from 100 to 2000 millidarcys. Thus, as a result of this work, accurate and complete analyses of rotary cores can be used as an aid in proper well completion, in determining the most profitable methods of utilizing[11] the native energy inherent to the reservoir, in later recompletion of wells to reduce water-production problems and in furnishing the operator with a knowledge of "the structure of the rock," which is the first need in any problem involving natural or secondary recovery of oil from a permeable reservoir formation.

Correlation of Sand and Producing Characteristics

(*Primary Recovery*)

The five-spot and radial-flow equation[9,10] relating sand, fluid and production characteristics have been verified time and again in the field for water-flooding networks. Its application to flowing wells takes on an even broader scope since natural production from the reservoir is limited by the available energy at discovery or through complete or partial maintenance of this energy by natural forces acting in or upon the field. Based on the permeability of sand to a homogeneous medium, it is possible to compute, with knowledge of the reservoir-fluid characteristics, the productivity index of any point or zone in a sand body. Within the same field where structural changes have not caused measurable changes in the reservoir fluid, the variations in productive capacity are indicated directly by the variations in permeability values. In several sand fields the measured and calculated productive indices compare as shown in Table 1.

The data of Table 1 possess greater significance than just an interesting comparison of calculated and actual productivity indices. Since permeability indicates productive capacity, it becomes possible to evaluate more accurately the economic recovery to be obtained from a volumetric or effective water-drive reservoir. It gives a basis which in the future can be used to determine the range of production rates for potentially effective natural water-drive reservoirs, and at the same time a method to evaluate the degree to which water drive will be effective in stimulating recovery.

TABLE 1.—*Comparison of Measured and Calculated Productive Indices for Wells Producing from Sand*

Line No.	Measured Productivity Index[a]	Calculated Productivity Index[a,b]	Method of Production
1	19.0	11.7	Flowing
2	15.4	11.2	Flowing
3	11.9	10.4	Flowing
4	6.3	5.6	Flowing
5	6.0	6.1	Flowing
6	2.1	1.62	Flowing
7	1.7	1.30	Flowing
8	0.81	0.72[c]	Pumping
9	0.64	0.60[c]	Pumping
10	0.62	0.77[c]	Pumping
11	0.52	0.45[c]	Pumping
12	0.28	0.29[c]	Pumping
13	0.17	0.21[c]	Pumping
14	0.12	0.16[c]	Pumping
15	0.043	0.050[e]	Pumping

[a] Barrels per day per pound drop in bottom-hole pressure.

[b] Calculated from core analysis and properties of reservoir fluids.

[c] Bottom-hole pressure in field has declined to 5 per cent of original. Calculated productivity index used the effect of free gas saturation on permeability to liquid.[12]

An interpretation of the measured and calculated indices for the pumping wells of Table 1 shows that by this comparison a method is developed whereby it is possible to evaluate the amount of recovery obtained from an area that has been affected by drainage. In other words, it is possible to compute the recovery obtained from the area to a given date and to calculate the future recovery expected by continued pumping or by installation of water drive. If uncontaminated cores, from areas of this type, are obtained, another index for both past and future recovery will be available. Additional records of this type should, with complete data, produce field results that confirm the previously outlined principles of well spacing in gas-expansion fields as developed by Muskat.[13]

PRESENT AND FUTURE APPLICATIONS

Sixty years ago Carll[1] recognized the relative efficiencies between production of oil by gas expansion and water drive, and stated that, in order properly to evaluate and apply these methods, a knowledge and understanding of reservoir flow must be available. Through analysis of cores while wells are being drilled, and by periodic sampling and analysis of produced fluids, we are today in position to apply a more complete knowledge of reservoir media and reservoir fluids to methods of increasing economic recovery. Large volumes of oil (Fig. 2) have been recovered by the successful application of waterflooding to fields where natural production had reached its economic limit. And we have found how: (1) to interpret probable production (whether it be gas, oil or water); (2) to calculate relative and absolute productivity; (3) to calculate normal connate-water saturation from contaminated cores; and (4) by the combination of these data to predict the rate and the ultimate recovery of oil from gas expansion and water-drive fields in keeping with maximum economic conservation of natural reservoir energy.

Field results have shown[8] and recent research on flow of gas, oil and water mixtures through sand[14-16] has confirmed, the presence of an equilibrium residual oil saturation after water drive. By adjusting production rates in potentially natural water-drive fields so that a minimum drop in reservoir pressure results, or by artificially supplementing this water drive by injection of extraneous water to maintain reservoir pressure and obtain profitable rates of production, it will be feasible to economically recover a larger portion of the original oil content. This will be accomplished by holding in solution, in the residual equilibrium oil saturation, the maximum amount of gas necessary to satisfy the minimum requirements of multiple-phase flow. Such a method of artificial maintenance of reservoir pressure will result in an even higher recovery than would be possible by later application of water drive after the reservoir pressure had fallen to a low value. *Its installation at an early date of production from the field, prior to a disturbance of the natural equilibrium present in the reservoir before discovery, will result in better control of irregular fluid movement through sands of varying permeability.* Producing wells will be flowed from their original completion to the point at which a high percentage of water is produced. At that point of depletion the ultimate yield will be from 2 to 2½ times as great as that which would be obtained from fields producing by gas expansion. Definite five-spot networks in deep fields with sands of higher permeability are not considered necessary in all cases. The correct plan is a systematic one that incorporates the lateral and vertical variations in sand thickness, permeability, and fluid content of the complete reservoir.

Under such a program it would be desirable to operate fields without original free gas caps at bottom-hole pressure in excess of the original saturation pressure for the gas-oil mixture. For above this pressure the operation is a hydraulic system, which, by virtue of the principles governing flow, becomes more efficient and has greater sensitivity and ease of control.

Cooperative work on the part of all operators in a field is essential to the successful installation of such a plan, if and when engineering data from the field indicate the absence of natural drive sufficient to maintain bottom-hole pressure at *economic rates of oil production.* Oil production by effective water drive is, as agreed by virtually all engineers at the present time, the most efficient method of producing oil. In such a program, spacing and oil recovery can approach the minimum and maximum, respectively, that is in keeping with optimum penetration of individual sand members. Development and operating costs will approach the minimum.

Conclusion

The basic considerations required in judging the effects of water movement into an oil reservoir are: "(1st) The time of flooding . . . , (2nd) The structure of the rock, (3rd) The shape of the area being flooded . . . , (4th) The point at which water is admitted, (5th) The height (which governs the pressure) of the volume of water obtaining admittance, (6th) The duration of the water supply," and (7th) The fluid characteristics and distribution. Today, as a result of recent work, we can intelligently measure, evaluate and apply these criteria, all but one of which (the seventh) were recognized by John F. Carll in 1880 as the basis for increased recovery through water drive.

With our present knowledge of the movement of fluids through oil reservoirs, it is possible, in keeping with judicious application of these basic principles, to develop and produce an oil field so that a greater recovery of the original oil content will be obtained at less cost per barrel. The prerequisite to profitable operation is the accumulation of representative reservoir media and reservoir fluid characteristics and a working knowledge for applying these data to field operations.

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DISCUSSION

(*Joseph Jensen presiding*)

J. E. SHERBORNE,* Los Angeles, Calif.—I believe that Mr. Lewis made a point that is worth emphasis when he said that the information necessary to properly develop a field should be obtained when wells are being drilled. The data can be obtained most economically at that time, and such information can be used to advantage in the early life of the field as well as for possible secondary recovery.

While the data presented in Fig. 1 show an increase in production rate for the two wells picked, no information is given regarding the condition of water input for the two areas. The question then arises: Would not the well-production curve shown in graph 1 resemble that shown in graph 2 if the rate of input for the well shown in graph 1 had been much less than it was for the conditions that existed? Is the inference correct that the input pressures for the areas shown in graphs 1, 2 and 3 of Fig. 1 are equal?

With regard to the same data, Mr. Lewis quotes from a report in which figures are given to show that from core analysis it is possible to predict the rate of recovery of oil by flooding. Is this report available in the literature?

In the paragraph on the mechanics of water-drive production, he says: "The conclusion from these data is that the production of oil from an artificial water-drive operation, at economic rates of production, takes place by the mechanism of positive displacement of the oil saturation that is present in excess of the final residual equilibrium oil saturation for the system, substantially in accordance with the permeability of the sand to homogeneous fluid flow." Does he mean that the rate of flow indicated by the permeability of the sand to homogeneous flow is that which will maintain in the formation, or that a value can be determined using an empirical relationship, based upon the permeability of the formation to homogeneous flow, which will permit an evaluation of the rate of movement of oil from that particular sand?

The correlation presented in Table 1 shows an excellent agreement between observed productivity indices and those calculated from core analyses. However, since it is my experience that, in general, productivity indices for individual wells change considerably with time, I should like to ask under what conditions the correlation is made?

J. A. LEWIS (author's reply).—The input pressure for the areas shown in graphs 1, 2 and 3 are approximately equal.

The report referred to has not been published in the literature. The quotation was taken from an intracompany core-analysis report, which was made prior to starting injection of water into the area.

Water injection and oil-production rates take place in accordance with the rates anticipated from permeability of the sand to homogeneous flow. Empirical correlations are necessary only where injection wells are heavily shot.

Productivity-index measurements were made on the flowing wells within six to nine months after completion. The reservoir pressure at time of test was equal to or near its value at discovery. Similar measurements were made on the pumping wells but, because of low reservoir pressure, a correction was necessary to account for the effect of gas saturation on permeability to oil.

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* Union Oil Company of California.

Geology and Development of the Paloma Field, Kern County, California

By James T. Wood, Jr.*

(Los Angeles Meeting, October 1941)

Stratigraphy, structure and closure of the Paloma field are discussed, with some details regarding the present state of development. The Paloma anticline, a large dome modified by faults, is the largest single closed dome in the southern San Joaquin Valley without surface outcrop or topographic expression. It owes its discovery to geophysics. Of nine wells drilled to the Stevens sand, seven are productive. The ultimate productive area may approximate 3000 acres when the limits of the field are determined.

Introduction

The Paloma field derives its name from the Paloma school, ½ mile north of what is now the center of the field.

The field is 17 miles southwest of Bakersfield, in the south central part of the San Joaquin Valley (Fig. 1). The present developed area and its expected extensions are in townships 31 and 32S., R.26E. It is the most southerly of several fields that produce from the Stevens sand zone.

The first well to produce condensate was a joint test drilled by the Western Gulf Oil Co. and The Texas Co. near the center of sec. 3, T.32S., R.26E., well No. 54-3. This well was completed on Aug. 31, 1939, at a depth of 10,178 ft. The initial production was 2280 bbl. a day of condensate and 14,750,000 cu. ft. of gas (½-hr. gauge) through a ⅜-in. bean.

Prior to the drilling of this well, the Ohio Oil Co. discovered and developed a small gas field, which embraces a part of three townships about their common corner but lies chiefly in secs. 31 and 32, T.31S., R.26E. The first well was completed on July 1, 1934, at a plugged depth of 5239 ft. after having been drilled to 7957 ft. Production was found in a 59-ft. zone 110 ft. below the Fourth Mya bed, within the San Joaquin clays. Until recently this field was known as the Buena Vista gas field. It is now carried by the Division of Oil and Gas as the Paloma gas field. Production within the Paloma gas field is derived from six wells, producing from several different zones in the interval from 4177 to 5548 feet.

Geology

Stratigraphy

The sediments penetrated by wells in the Paloma field range in age from Recent to Upper Miocene. The entire section, which exceeds 10,000 ft. in thickness, conforms generally to the standard section of the south central San Joaquin Valley. The producing zone, sometimes called the Paloma sand, is the approximate equivalent of the Stevens sand zone of the Ten Section, Canal, Coles Levee and other fields. The stratigraphic section is shown in Table 1.

*Paloma Producing Zone** (*Stevens Sand Zone, Upper Miocene*).—The Paloma producing zone (Fig. 2), frequently referred to as the Paloma sand, is encountered at depths ranging from 9950 to 10,300 ft. In general, it is a massive, firm to hard, not too well sorted, fine to medium fine sand. It is interbedded with thin, hard, calcareous sand shells of similar texture and cherty

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* Manager, Producing Department, The Texas Company, Los Angeles, California.

* Commences with first sand below base of chert zone (100 ft. ± below the *N* point) and continues to top of *Pulvinulinella gyroidinaformis* zone.

TABLE 1.—*Stratigraphic Section, Paloma Field*

Age	Formation	Thickness, Ft.	Description
Quaternary	Alluvium	1000 ±	Incoherent sands and shales.
Pleistocene	Upper Tulare	850–1200	Friable sands medium to fine-grained with beds of gray-green or brownish mottled sandy clay having infrequent thin beds of fresh-water fossils. Water near base changes from fresh or mildly brackish to salty, as shown by electric logs.
Pleistocene	Lower Tulare	1850–2200	Sand beds less numerous than in the section above, due to thickening of intervening gray-green or brown mottled shales. Carbonaceous material more abundant, with occasional thin seams of lignite or lignitic clays, one of the latter attaining a recorded thickness of 6 feet.
Upper Pliocene	San Joaquin Clays	1450–1500	Predominantly clays, with interbedded fine-medium-grained sands, intervening between the top of the First Mya bed and the top of the Upper Mulinia bed. Fresh-water and marine fossil zones alternate throughout the section. The five Mya zones as well as the Upper and Lower Scalez and the "Stinking Brown Shale" have all been recognized.
Middle Pliocene	Upper Etchegoin	2570–3300	Essentially a sandy zone with intervening shales. Sands vary from silty and fine grained to coarse with excellent porosity and permeability. Difficult to correlate from well to well, owing to lenticularity. Sands increase in abundance and coarseness to east, and shales decrease. Marine fossils scattered throughout but decrease in abundance with depth. Basal sands reach lower and lower into stratigraphic column from west to east.
Lower Pliocene	Lower Etchegoin	250–975	A transition zone of dark gray to greenish gray claystones lying between the above sandy section and the brown shale. Generally regarded as lowermost Pliocene. Contact with underlying brown shale is gradational and is placed where shale body assumes a definite brownish hue.
Upper Miocene	Brown Shale	860–970	A claystone massive and dull grayish brown at top grading within 100 to 200 ft. into dark, greenish brown clay shale. A chert streak appears about 360 ft. above the base, which grades into an almost continuous light brown cherty zone that constitutes the base of this member. Top of continuous chert corresponds to the *N* point of electric logs. This point can be picked in other Stevens-sand fields such as Ten Section, Canal and Coles Levee. In the discovery area the chert zone rests upon the Paloma producing sand. To the east in the Western Gulf B-12-12, this zone is largely replaced by a sand known as the B-12-12 sand.
Upper Miocene	Paloma Producing Zone (Stevens Sand Zone)	300–390	See special description in text.
Upper Miocene	Lower Stevens Zone	796 ±	See special description in text

or dark brown siliceous shales. One conspicuous shale bed varying from 10 to 50 ft. in thickness generally occurs within the upper 100 to 150 ft. of sand.

Fresh cores from this zone have been characterized by light tan distillate stains and have a strong gasoline odor. When dry the same cores have an unpleasant smell, described by one observer as a "sour sock" odor. Material resembling Grahamite and giving a dark cut with carbon tetrachloride is frequently found in the sand.

The total effective sand thickness of the productive zone at Paloma is estimated to be from 200 to 250 ft. in the wells now completed. Core analysis indicates an average porosity of about 20 per cent and an average permeability somewhat less than 100 millidarcys. Streaks of sand having permeabilities of 100 to 500 millidarcys are found throughout the section, but doubtless these are of limited extent, as they do not correlate from well to well.

The base of this sand rests with fairly sharp contact upon the underlying Lower Stevens zone.

Lower Stevens Zone (*Upper Miocene*).—The Lower Stevens Zone is composed chiefly of dark brown semisiliceous and cherty shales, often finely laminated. These shales are infrequently interbedded with sands, which, while similar in texture to those in the producing zone, are in general hard and calcareous. This zone had a thickness of

780 ft. in Ohio K.C.L. A-8 and 796 ft. in Western Gulf K.C.L. A-74. Both wells were bottomed above the *Pulvinulinella gyroidinaformis* zone, which is considered to be the base of the Stevens zone. Neither well was productive in the Lower Stevens zone. The potentialities of the formations below the sections penetrated by these wells are unknown.

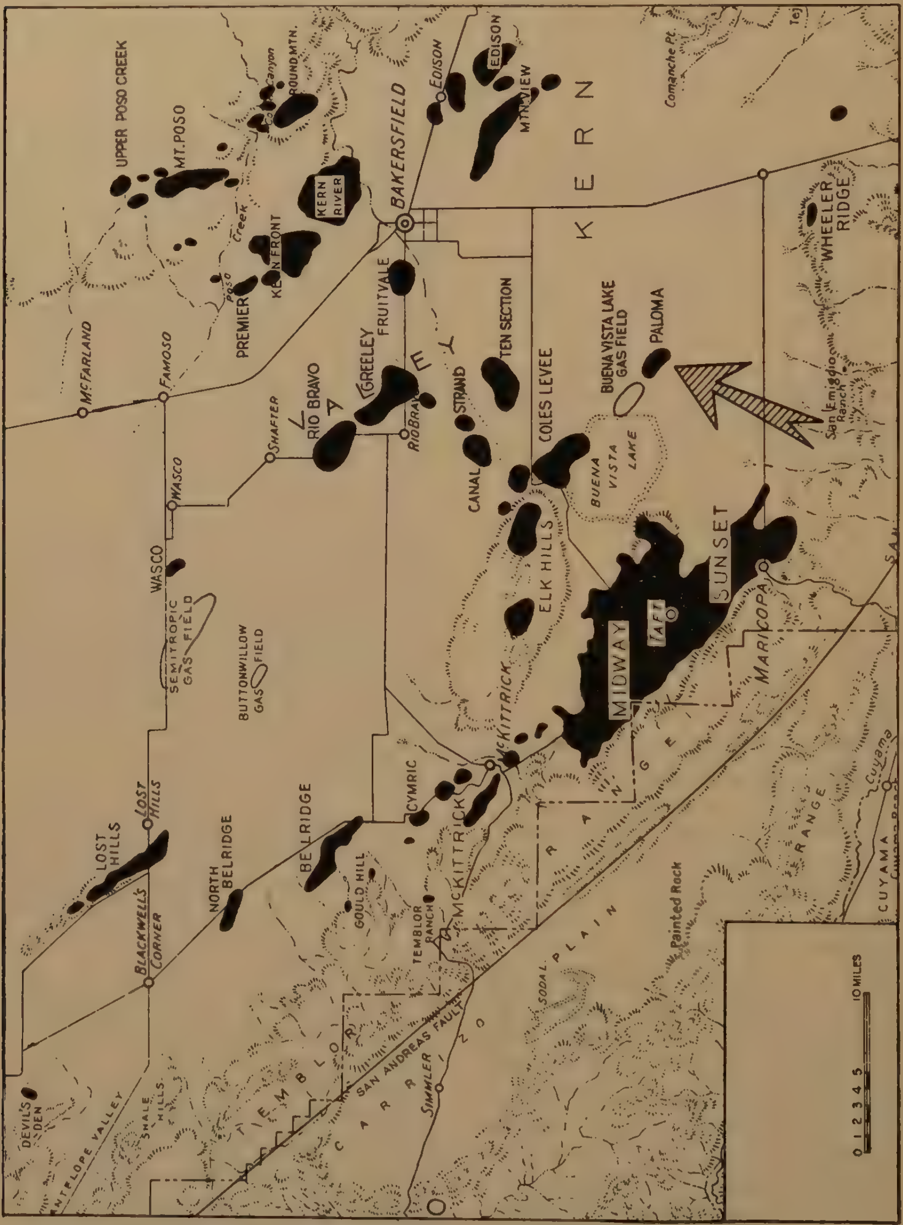

FIG. 1.—PALOMA FIELD AND ADJACENT FIELDS, KERN COUNTY, CALIFORNIA, SEPTEMBER 29, 1941.

Thickness and Distribution of Paloma Producing Zone.—Development is still too limited to define the thickness, distribution

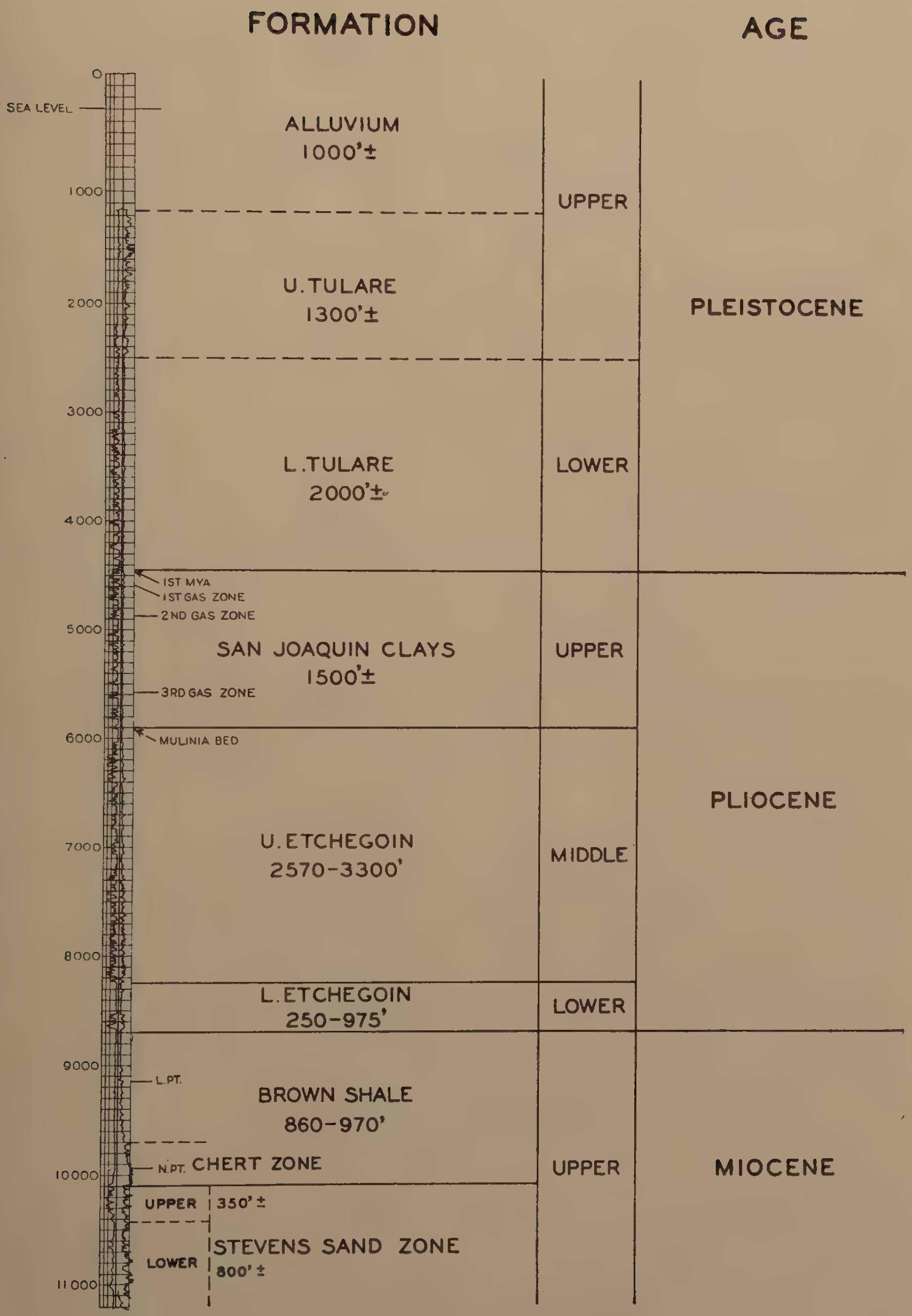

FIG. 2.—STRATIGRAPHIC SECTION, PALOMA PRODUCING ZONE.

and reservoir characteristics of the producing zone throughout the Paloma field. With but one or two exceptions, the wells drilled to date have been located along lines of nearly equal sand thickness. Western Gulf B-12-12 is approximately ¾ mile south of an east-west line passing through the present producing wells. If the upper 90 to 125 ft. of sand in this well is conceded to be a new member, the Stevens sand as known elsewhere in the field has decreased in thickness. Union Oil Company's Morgan No. 81-14, sec. 14, T.32S., R.26E., was abandoned at a depth of 11,456 ft. This well penetrated approximately 285 ft. of sand between 10,640 and bottom. Approximately 213 ft. of sand between 10,640 and 10,853 is considered the equivalent of the B-12-12 sand. The remainder of the sand, approximately 72 ft., occurs between 11,010 and bottom. These sands may be the equivalent of the Paloma producing zone.

Although there are some indications of both thinning and decreasing permeability in the Paloma producing zone southwest of the axis of the structure, more development is necessary before either the southwest or northeast flank can be evaluated.

B-12-12 Sand.—The B-12-12 sand, discovered by Western Gulf B-12-12 early during the current year, is at present confined to the easternmost producing well within the Paloma field. This well's productive zone includes 496 ft. of formation, of which an estimated 260 ft. is sand. The upper 90 to 125 ft. of this sand occurs as a replacement of the chert zone and a small portion of the immediately overlying brown shale.

So little is known at present of the distribution of this sand that it does not merit a great deal of mention other than to say its featheredge lies somewhere between Western Gulf B-12-12 and the next producer to the northwest, Western Gulf A-34. From theoretical considerations and an application of regional geology, it is believed that the featheredge of this new sand will maintain an approximate north-south trend. This means that the B-12-12 sand will be draped about the eastern plunge of the Paloma anticline, and it is anticipated that as it goes down the plunge eastward this sand will expand in thickness and increase in permeability and porosity. Western Gulf Symons 12-7, now drilling exactly one mile east of B-12-12, will test this theory.

Most Reliable Markers for Correlation.—For correlation, the most reliable markers are, from top down, the electrical markers, *L* point, *MM* point, and *N* point, all being within the Miocene brown shale. Intervals between them are approximately 460 and 375 ft. As stated previously, the interval from the *N* point to the top of the Paloma producing zone proper is about 100 feet.

Structure

The Paloma anticline is believed to be a single large dome modified somewhat by faults, the exact position and details of which are still unknown. The Paloma field is lower structurally than any of the San Joaquin Valley fields that produce from the Stevens sand zone, it being the only one in which drilling below 10,000 ft. is necessary to reach this sand (Fig. 3).

South of the Paloma anticline lies the large, structurally deep Buena Vista-Kern Lake synclinal basin into which, it appears from regional studies, were discharged the Stevens sands and other sediments representing their time equivalents along the southwestern edge of the San Joaquin Valley. It is to be expected that these sands grade into richly organic shales toward the center of this basin. This area, to a believer in lateral migration, appears to be the most likely source of much of the oil now accumulated in Stevens sand fields. The low point in this basin is probably at least 3500 ft. lower than equivalent measures on top of the Paloma anticline.

Closure

The Paloma anticline is the largest single closed dome in the southern San Joaquin Valley without surface outcrop or topographic expression. It owes its discovery entirely to geophysics. This fold has a known length of 9 miles, with an indicated geophysical closure of 500 ft. The reversal against the regional dip on its northeastern flank is 1000 ft. opposite the apex of the dome. The vertical relief between the apex and the syncline on the south exceeds 3500 ft. The breadth of the north flank, from anticlinal axis to synclinal axis, is approximately 2 miles.

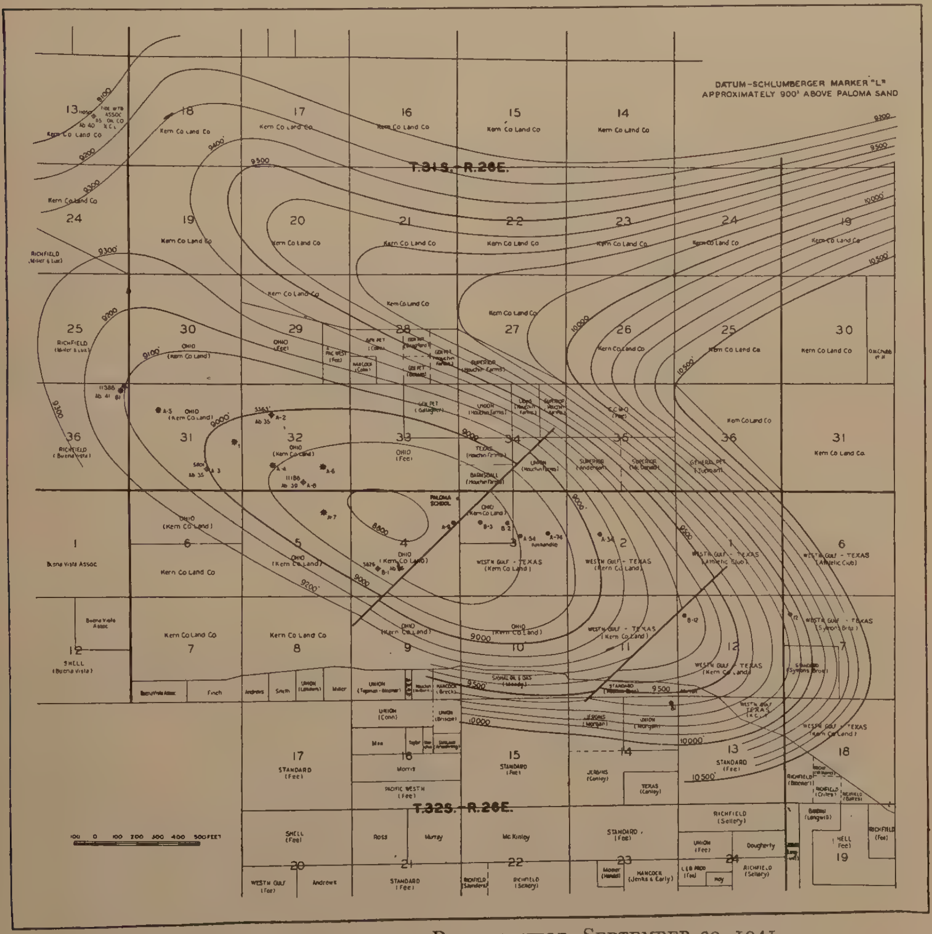

FIG. 3.—STRUCTURAL MAP, PALOMA FIELD, SEPTEMBER 29, 1941.

The productive closure—that is, the vertical relief from the top of a given productive sand at its highest point to the bottom of the lowest dry well within that sand, exceeds 811 ft. by an unknown amount. This figure is obtained by subtracting the subsea-level depth to the top of the Stevens sand (9644 ft.) in Ohio B-3 from the subsea-level depth of Western Gulf B-12-12 (10,455). Subsequent development may prove that stratigraphic closure by lateral change of facies is an important factor in accumulation.

PRESENT STATE OF DEVELOPMENT

Nine wells have been drilled to the Stevens sand in the Paloma area; all capable of producing except two—Ohio Oil Company's A-8, near the south quarter corner of sec. 32, T.31S., R.26E., and Union Oil Company's Morgan 81-14, sec. 14, T.32S., R.26E. (abandoned 9-30-41). A-8 was the first in the area to penetrate the Stevens zone. Although the prospects for production seemed good, the well failed to produce and since has remained something of a mystery. Union Oil Company's Morgan 81-14 penetrated approximately 200 ft. of sand, believed to be the equivalent of the B-12-12 sand. This sand did not, in the opinion of the operator, warrant a test. Western Gulf Oil Company's Symons Bros. Development Co. No. 12-7 is now drilling at 11,021 ft. This well is in sec. 7, T.32S., R.27E., and is lower structurally than the Union Morgan No. 81-14.

The seven productive wells, three of which were drilled by the Ohio Oil Co. and four by the Western Gulf Oil Co., have an average depth of 10,467 ft. The deepest well drilled in the field is Western Gulf 74-3, which was carried to a depth of 11,422 ft. and later plugged back to 10,700 feet.

The drilling program to date has been to set a 13⅜-in. surface string between 1200 and 1300 ft. A 7-in. water string is then set above the sand at approximately 9500 ft., followed by a 4¾-in. shop-perforated liner on bottom. A majority of the wells are completed with 2-in. tubing.

The ultimate productive area has been estimated to be from 3000 to over 5000 acres. A number of additional wells must be drilled before the field is definitely defined.

A Plan for Operation of the Paloma Field

By W. H. Geis,* Member A.I.M.E.

(Los Angeles Meeting, October 1941)

The following pages summarize the causes that led to the suggestion of unit operation of the Paloma field, the organization of committees, preparation of the Paloma Operators Agreement and the reasons for rejection of the plan.

Introduction

Long ago an Austrian physicist observed that under certain conditions the condensation of a liquid from gaseous mixtures resulted from pressure reduction. Some 50 years later he would have known that his research was not in vain. He would have seen a group of serious operators and engineers seeking to apply that principle to a conservation program for unitized production in the Paloma gas field—but he would also have been saddened to see that forces unsympathetic to the application of science in oil production, with little or no appreciation of modern methods and the advantages of cooperation, so far have prevented the adoption of that program.

Soon after the Paloma field was discovered it was realized that all the hydrocarbons in the reservoir existed in the gaseous phase. This condition was confirmed over a large area. Therefore, if the field was to be properly exploited with the greatest ultimate recovery of condensate, the hydrocarbons in the reservoir must be produced in the single or gas phase. They must be cautiously extracted with the least possible reduction of the natural pressure. If this could be accomplished, or if artificial pressure control were utilized, the condensation and underground loss of the valuable distillate would be preventable—otherwise it would not be.

Wholehearted cooperation of all operators was required in order to accomplish the conservation purposes of the program. To this end the production engineers of the several companies concerned lent their time and talents. They fully investigated the physical relationships of the products within the complicated gaseous mixture, prepared extensive reports on the subject and drew up a reasonably efficient plan of operations, which now is commonly called the "Paloma Unit Plan" but actually was entitled "The Paloma Operators Agreement."

All of the engineers were not in perfect agreement on all the features of the plan, or even on all the engineering principles. However, it is safe to say that on all the important or essential factors there was a unanimity of opinion, particularly as to the objectives. These were fairly simple and reduce to one controlling item, "pressure control" by cycling or recycling.

Organization

The principal operators initiated the program by calling a meeting of all the lessees in the area, at which an organization was perfected, known as the "Paloma Operators Committee." Various subcommittees were appointed to expedite the work, including an "Engineering Committee." These functioned in a businesslike manner, frequently reported to the superior committee and

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thus directly to the operators. Each operator had a member on the Operators Committee.

Lessors were only informally organized. Several meetings were held at which the physical conditions, technical as they were, were fully explained and the consequences of ordinary competitive production emphasized. Numerous articles appeared in the newspapers and trade magazines, so that no one interested in the field could take the position that he was not advised.

Plan Versus Competition

It was contended, without dispute, that if the field were exploited in the competitive fashion whereby each operator sought to complete the first, and the most, wells on his property and thereafter to produce, or induce, a pressure low on his property, only one fourth to one fifth of the otherwise recoverable liquid (condensate) would be saved in the tanks. These estimated recoveries were never fully authenticated but the accepted figures were 21,000 bbl. per acre recovery by pressure control and 4000 to 5000 bbl. per acre without such control. In view of the extent of the field, the risk was a recovery of 100,000,000 bbl. of liquid and all the gas, compared with 20,000,000 to 25,000,000 bbl. of liquid and an indeterminate although undoubtedly a large amount of the gas. Thus the probable losses resulting from competitive production were enormous. Opportunity for a handsome profit, and an assured one, could be changed easily into a discouraging financial failure.

Prevention of such a loss was quite simple. Through a central plant the liquid could be recovered at a predetermined and practical rate, as a water-white product of about 60° A.P.I. gravity containing some 50 per cent of fighting-grade aviation gasoline. The residual gas could be returned to the reservoir to provide pressure control, later extracted and sold as dry gas. All would benefit by pressure control—some more, others less, but everybody would be ahead of the competitive system from the standpoints of both reduced costs and increased recoveries.

Variables to Be Considered

A few operators were sufficiently rugged in their individualism, an otherwise admirable characteristic, to insist that the specific relationship, or equity, of each land parcel to the whole must be determined. If this were not done they would, and did, resist the plan, which necessarily had to be unanimously accepted. Equities are apt to involve not only the area of participation but sand thicknesses, porosity, permeability, saturation and many other factors varying from place to place. There are a number of important intangibles, which may never be known but upon which specific equities may depend. Even complete knowledge of one variable within a group of several is of little or no help in the solution of such a problem.

Geological structure in itself was a variable in the equation. The area had been "shot" by seismic surveys many times, both before and after the discovery, but while each map differed from another a composite of all could be used as indicative of the underground configuration. The well data indicated that the Paloma sand thickened shoreward along the axis and to the southeast. Permeabilities decreased in the opposite direction, becoming practically zero west of the section line separating sections 4 and 5 (T.32S., R.26E.) beyond which two dry holes had been drilled in sec. 5, T.32S., R.26E. and sec. 36, T.31S., R.25E.

Southeast from the point of zero permeability, seven wells had been completed, proving four miles along the structural axis. These wells were highly productive and revealed the reservoir conditions. Therefore while a freshman geologist could tell that the structure was large and of great potentiality, no one not present when the sand was laid down could determine the specific relationship of each land parcel to the other parcels or to the whole unit area. This, however, only introduced the gambling element for which the oil operators are reputedly well known, but which failed to materialize in this case.

Basis of Participation

The operators all knew the conditions and the Committee had to find a yardstick with which to measure them. It settled the question by deciding that participation should be on the basis of acreage only. If 5000 acres were included within the plan, each 80 acres enjoyed 1.52 per cent of the total recovery from the pool and bore the same percentage of the costs. In accepting this provision, the larger operators and owners had to grant concessions, since the greatest known sand thicknesses were on their lands. The decision may or may not have been fair but resolved itself into balancing one equity or variable against another. All then that remained was to fix the area and the boundary line. This presented "field day" possibilities for trading proclivities.

Studying Fundamentals

Most of the companies had previous experience with unitization efforts in California and realized the tendency of each unconsciously to be influenced by his own interests. Even when eminently fair, motives are frequently misunderstood. Therefore, the Committee decided to turn the entire matter over to a complete outsider. Some one with no California affiliations, prejudice or favoritism, but with wide experience in retrograde production and unitization. Preferably it should be one who had never even heard of Paloma. It was tacitly decided, if not actually, to abide by the decisions of such a person or firm if one with the somewhat unusual qualifications could be found. A subcommittee was appointed to find qualified people and report their names to the Operators Committee, which would then make the selection.

Members of the subcommittee journeyed into Texas and Oklahoma and personally investigated the qualifications of many individuals and consulting firms and presented a list thereof to the Operators Committee. Finally a selection was made; the engineering firm selected accepted the commitment, and was charged by the Committee to do the following:

1. To study the physical conditions in the field in confirmation of the retrograde aspects.
2. To make adequate field tests on a commercial basis in confirmation of laboratory tests.
3. To determine upon the area to be unitized.
4. To prepare and present to the Committee a complete plan for unit operations.
5. Upon the request of the Committee, to design the proper type of plant and supervise its construction.
6. To consult with the landowners and explain all features of the Plan.
7. To prepare a Consent Agreement for the signatures of the landowners, permitting the lessees to join in the Plan.
8. To assist the lessees in obtaining changes in the various leases where required.
9. To do whatever might be necessary to assure a soundly engineered Plan.

It must be admitted that the consulting engineers performed their work in an admirable and professional manner. They could analyze most of the factors and reach sound conclusions, but there was one thing they could not analyze—the idiosyncracies of human nature.

Before the consultants were employed an engineering report was available from the laboratories of the California Institute of Technology. This report was conclusive and set forth the pertinent characteristics of the gaseous mixture. Similar investigations were in progress at the laboratories of the Gulf Corporation at Pittsburgh, so that when the consultants had concluded their report the Committee had the benefit of three independent investigations (and conclusions). It later proved that all the reports were so nearly identical that no doubt could possibly remain as to the manner by which the field would have to be developed and produced.

As the consulting engineers made their investigations each company laid its engineering files open for inspection and otherwise assisted whenever called upon. As the data were accumulated, duplicate files were acquired by the Engineering Subcommittee of the Operators Committee. Thus any conclusion or statement made by the consultants could immediately be checked if desired by any operator.

Fixing the Boundary Line

It would be presumptuous for anyone other than the consultants to say that he is aware of all the data and circumstances that led to the final fixing of the boundary line of the unit. It is known, however, that after the consultants had arrived at a conclusion they obtained from each operator his opinions, objections and suggestions as to the position of the boundary line. These were reviewed for errors by the engineers and a map of the final area for unitization was presented to the Committee with a formal report from the consultants.

The writer, as Chairman of the Engineering Subcommittee, checked the position of the boundary by superimposing five geophysical maps over the land plot and came to the conclusion that on the northwest, north, northeast, east and southeast the position was justified on a structural basis. On the west, southwest, south and extending southeastward, the position was justified by isopach and "isoperm" considerations. Since the line was fixed, a well has been drilled at the southeast extremity of the unit. The information obtained therefrom seems to indicate that the consultants had placed the line within ¼ mile of the featheredge of the gas-water interface. Cores from the well showed some gas and oil through a short interval. These were considered insufficient to warrant a test and the well was abandoned.

This story of the unitization effort is told in some detail in order to indicate that the Operators Committee went to extremes to limit the personal equation. The Plan failed of acceptance because of two things: (1) the refusal of a minority to accept the position of the boundary, and (2) the possibility of a black oil ring existing between the gas cap and the edge water.

The consultants reported that a black oil ring might exist between the gas and the water line. Such a ring must be very narrow, since little width remains between the known extent of the gas cap and the position of the edge water. Even if oil does exist, a little simple arithmetic will show that with oil at $1.25 per barrel the land must produce 30,000 bbl. per acre to equal the equivalent returns from participation in the unit.

Considerable criticism developed as to the size of the unit, although no one claimed that it was too small. When analyzed as to where it was too large, some contended that it extended too far to the north but not far enough to the southwest; others, too far to the west but not to the southeast. In general, the unit was too large in the direction of a competitive company's holdings, not large enough in the direction of one's own, but over-all too large. So universal were these complaints, but conflicting within themselves, that they justified rather than condemned not only the size of the unit but its configuration.

An essential part of the plan provided that all productive land be included; for if any were excluded and later became productive the whole unit would be subject to severe drainage. Therefore the tendency was to expand the area solely as a safety measure for those with definitely proved lands. Even if barren lands were included, sacrifices could well be made for the assured protection of all. It was an easy task to delimit the minimum productive area but extremely difficult to outline the maximum limits. To a certain extent flexibility on these factors was provided in the Plan, although once a parcel was included it could not be excluded except under exceptional circumstances.

PREPARING THE AGREEMENT

In the preparation of the "Agreement" the Operators Committee again used meticulous care in safeguarding the rights of all. After the consultants had concluded the engineering investigations, they presented a written document setting forth the fundamental terms of an agreement. This was turned over to a subcommittee composed of nine oil company attorneys for final preparation. Every operator in the area was permitted to have a member on the subcommittee.

Legal difficulties and divergent viewpoints of both the attorneys and the practical operators were finally reconciled and a document complete in all details was presented to the Operators Committee. The work of the subcommittee was fraught with many difficulties and it stands to its credit that no serious complaint has been registered. Each operator approved the document as such even if he disagreed with certain of the provisions contained therein.

The legal Subcommittee also prepared a document entitled "Lessors' and Royalty Owners Consent," which required the signature of those parties before the unit plan could become effective.

Here, the reader is referred to the documents themselves for the detailed provisions of the Plan. Together they comprise 19 typewritten pages, so only a review of the essential provisions can be included here.

SUMMARY OF THE "PALOMA OPERATORS AGREEMENT"

The Agreement was dated May 1, 1941, and was to become effective after four lessees had signed, representing at least 50 per cent of the unitized acreage, and after the Plan had been approved by the State Oil and Gas Supervisor. All lessees were required to sign before July 1, 1941, or thereafter they could join the Plan only with the consent of the Operators Committee. It was to remain in effect as long as the lands produced or until terminated by unanimous consent.

The preamble set forth that unit operations were in the public interest to conserve a natural resource and prevent avoidable waste. This could be accomplished by the maintenance of pressure, creation of gas drive, and by systematic cycling under a unit plan.

Various terms used in the contract were defined, among which was a description of the "Paloma Field" and in the "Paloma Zone." The latter was the then producing measure as found in seven specified wells but included any other sands that were "pressure connected" therewith. The field was divided into two classes of lands, "controlled" and "participating." The controlled lands were all the lands owned by any signatory within the description of the field. The participating lands were those within the area established by the consulting engineers, and immediately participated in the benefits of the unit operations. Thus within the controlled lands a company might have both participating and nonparticipating lands.

Prior to Jan. 1, 1946, the Operators Committee could, by a three-fourths vote, bring into the "participating" lands any of the "nonparticipating" lands. Thereafter it could do so only with the consent of the lessee and lessor. If a well had been drilled thereon, the owner would be compensated therefor. Under certain conditions the owner would receive twice the cost of such a well.

A geometrical formula was provided for determination of the amount of non-participating land, proved by a successful well, which automatically had to come into the unit prior to Jan. 1, 1946. These various provisions provided for the expansion of the participating area, but no land was ever to be excluded except for title defects.

It was apparent that the Operators Committee expected all lands in the field to be proved before January 1946, and included within the participating classification. But the door was not closed if the Committee erred in its judgment; it only cost the operating group twice as much for the well and permitted the operator to stay outside the unit if he desired. Thus the actual fixing of the boundary line of the unit was not relatively important and did not exclude any land. Consequently the criticism of the line was not well founded. If an operator felt that the engineers had made a mistake, he could prove his point by drilling a well on the disputed land. If it were dry he had to pay for it himself; if it were a success, he could get paid twice over and force acceptance of much of his additional land within the unit. The only relief that the agreement did not afford was the adverse weighting created by including too much land within the participating lands in the first instance. This weighting, when converted into a participating percentage, was nominal, for the unit was very large in area.

The Agreement further pooled all the land within the participating area for the production of all hydrocarbon substances. As previously mentioned, the benefits and burdens were based pro rata upon acreage. An Operators Committee was created, representation thereon defined, and directed to "plan, coordinate, and manage or conduct the development and operation of the participating lands . . . " Specific powers and duties were set forth in considerable detail, with a mandatory obligation to construct a modern plant for high-pressure condensate recovery and cycling.

Careful reading of the Agreement will reveal that the products produced from the unit belonged pro rata to the individual companies and royalty owners, and were to be delivered in kind. The Committee was simply operating as the agent of the owners. There was no transfer of title. There were many other important provisions in the Agreement, which clarified the purposes and the intentions of the parties and references made to the document as a model for unit operations.

Reasons Plan Was Not Adopted

It should be remembered that the writer was closely identified with the unitization effort as Chairman of the Engineering Subcommittee, and repeats the history as it appeared to him. Criticism for failure to adopt the Plan is not directed at any company, individual, or group. In retrospect, all seem more or less guilty of somewhat narrow viewpoints in light of the advantages that could have been obtained. Details became overemphasized while fundamentals were forgotten. A company would yield on one point and remain adamant on another, until at the conclusion there was an unyielding position by someone on every point, but with all the difficulties there was never any personal animosity. The lessors were as much to blame for the failure as were the operators.

Chapter II. Engineering Research

Effectiveness of Gravel Screens

By B. H. Sage,* Member A.I.M.E., and W. N. Lacey*

(Los Angeles Meeting, October 1941)

The results of an extensive experimental program relating to the effectiveness of gravel screens have been correlated. The factors considered in some detail include gravel size and condition of packing, sand size and size distribution, fluid velocity, fluid viscosity, and thickness and arrangement of gravel screens. Good agreement between calculated values based upon probability considerations and experimental results relating to the influence of the thickness of the gravel screen was obtained. All of these factors are treated in the correlation in order that their influence may be taken into account in ascertaining the characteristics of an effective gravel screen for a particular set of conditions. The details of the experimental program are not given in the present paper but a description of generalized behavior and typical experimental results are recorded in graphic form.

Introduction

Gravel screens have been placed in water and oil wells for a number of years[1,2,3] with the dual objective of increasing the productivity and decreasing the entrance of sand into the well bore. An understanding of the factors controlling the effectiveness of gravel screens in this connection is of industrial interest because it will lead to the proper selection of gravel. Some of the fundamental considerations involved in the migration of sand through a coarser body of porous materials were investigated by Coberly and Wagner[4] and further experimental work has been carried out by Gumpertz.[5] Apparently the pertinent phenomena are somewhat complex and are influenced by many variables. The present paper deals with the prediction of the behavior of gravel screens under the conditions encountered in practice but does not attempt to discuss the experimental methods or results that were obtained as a background and upon which the prediction is based.

Influence of Gravel Screens upon Productivity

The use of a gravel screen may increase the productivity of a well by increasing its effective diameter, and this constitutes one of the objectives of its use. The permeability of most gravels and coarse sands that are employed in practice is so large compared to that of the sand in place that relatively little loss in production rate will arise from the use of material fine enough to cause the desired resistance to sand migration. For example, in Fig. 1 is depicted the approximate variation in the permeability of closely sized spherical gravels under the conditions of packing likely to be encountered in screens. The dotted lines indicate the variation that might be found because of differences in packing. It should be realized that the permeability is not a single-valued function of the average grain diameter but is related to a large number of factors, including the size, the size distribution and the shapes of the particles. However, Fig. 1 does permit a rough estimation of the permeability of closely sized spherical gravels and shows that the permeability with even the smaller particles is very large compared to that of most petroleum production horizons.

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* California Institute of Technology, Pasadena, California.

[1] References are at the end of the paper.

The influence of a gravel screen upon the productivity of a well having a liner of 4-in. diameter is shown in Fig. 2. The curves correspond to varying ratios of the permeability of the formation to that of the screen. These results were obtained by application of the following expression, which is based upon the assumption of

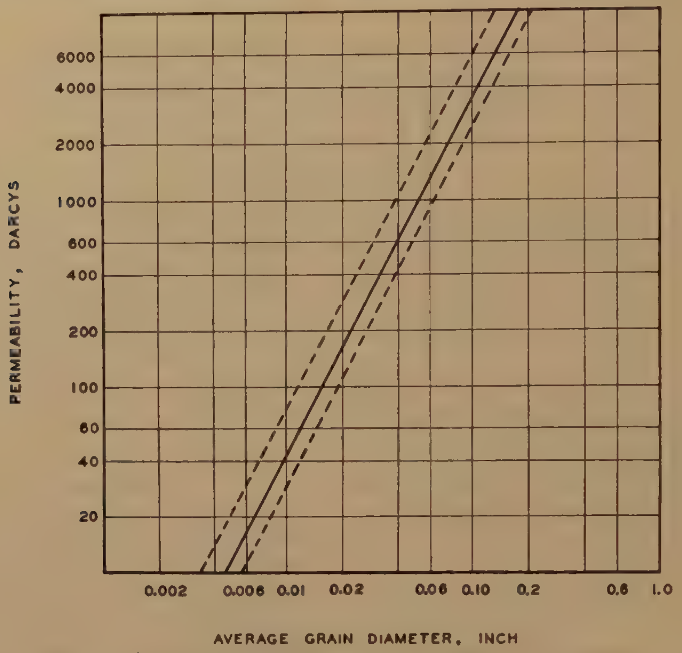

FIG. 1.—APPROXIMATE PERMEABILITY OF SPHERICAL GRAVELS.

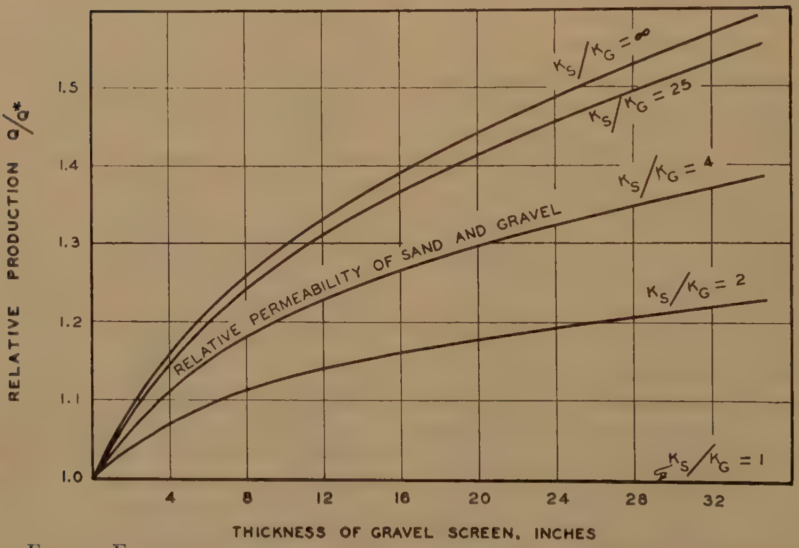

FIG. 2.—ESTIMATED INFLUENCE OF GRAVEL SCREENS UPON WELL PRODUCTION.

radial homogeneous isochoric viscous flow:

$$\frac{Q}{Q^*} = \frac{k_g}{k_s} \ln \frac{r_b}{r_w} \Big/ \left(\ln \frac{r_p}{r_w} + \frac{k_g}{k_f} \ln \frac{r_b}{r_p} \right) \qquad [1]^*$$

Results from this equation indicate that the effectiveness in increasing productivity by means of a gravel screen with a particular configuration increases as its permeability increases but at a decreasing rate. If the ratio of permeabilities is in the order of 25, there is little more to be gained by increasing the permeability of the screen even to a marked extent. Likewise, the effectiveness of a gravel screen increases with its diameter, but this effect also decreases in magnitude at larger diameters.

SCREENING INFLUENCE OF GRAVELS

The second objective of a gravel screen involving the retention of the particles of sand at the outer periphery of the screen is equally important to the increase in production resulting from its use. Furthermore, in order to realize the first objective it is necessary that the gravel screen remain relatively free from sand. It is desirable therefore to predict the optimum size of gravel that should be used in order that nearly all of the sand body may be retained in the first several rows of gravel screen.

The migration of sand particles through a coarser porous medium is a complex physical phenomenon and is influenced by such variables as particle size, size distribution, conditions of packing, size and size distribution of screening material, velocity of fluids flowing and their properties. It is desirable, so far as feasible, to take into account all of these parameters in predicting the behavior of a gravel screen.

THEORETICAL CONSIDERATIONS

It is possible, on the basis of numerous simplifying assumptions, to predict in a general way the influence of the geometry of the screen upon its resistance to the migration of solid material. However, the effect of hydrodynamic flow conditions cannot be so simply treated and must as yet be established experimentally.

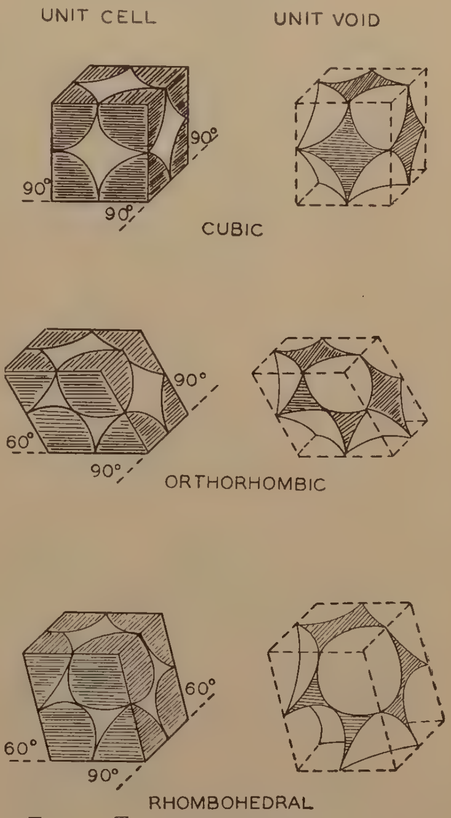

FIG. 3.—TYPES OF SYSTEMATIC PACKING.

The conditions of packing of the screening material exert a rather marked influence upon the resistance of a gravel screen to the migration of solid particles, since the type of packing influences the size of the interstitial spaces to a marked extent. Many "haphazard" types of packing may be encountered but the more probable cases of systematic packing are limited to three general types[6] shown in Fig. 3. As a simplification, it will be assumed that any packing is made up of these three fundamental types in varying proportions. On the basis of this assumption, the porosity

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* Nomenclature at the end of the paper.

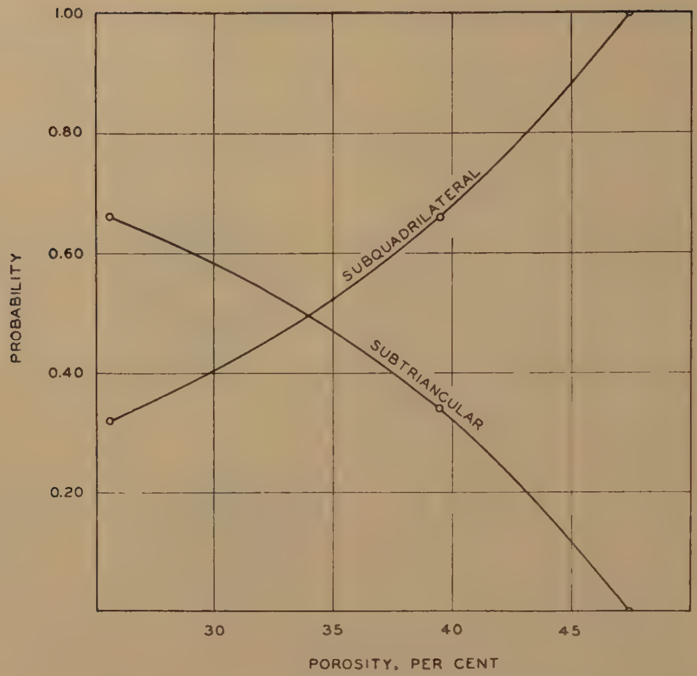

FIG. 4.—OCCURRENCE OF TYPES OF OPENING BETWEEN SPHERICAL PARTICLES.

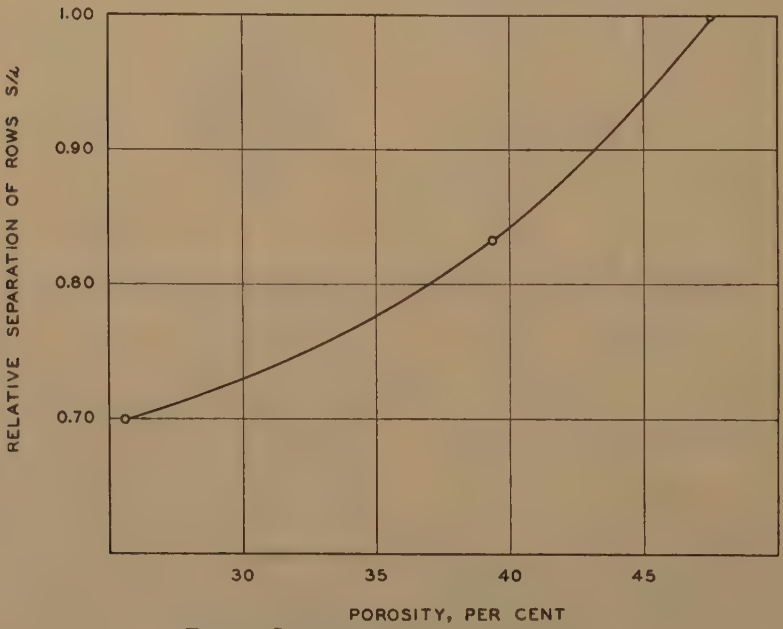

FIG. 5.—SEPARATION OF ROWS OF PACKING.

of the gravel affords a simple macroscopic parameter, which may be employed to estimate approximately the statistical conditions of packing. This single parameter is insufficient to describe with accuracy the configuration obtaining but it does indicate in at least a qualitative fashion the nature of the interstitial spaces.

The minimum interstitial spaces encountered in passage through a unit cell[6] of cubic packing are subquadrilateral openings (Fig. 3), while in orthorhombic packing the openings on only two of the sets of opposite sides of the unit cell are subquadrilateral and the openings of the opposite set of faces are subtriangular. Therefore the probability is that two thirds of the transported particles may encounter subquadrilateral openings while one third encounter subtriangular openings. Rhombohedral packing yields subquadrilateral openings on only one set of opposite faces and subtriangular openings on the other two sets. If this type of packing persists throughout the body of porous material, the probability of encountering subquadrilateral openings is one-third and of subtriangular openings, two-thirds.

If it is assumed that the porosity is a measure of the frequency of occurrence of these three types of packing, the probability of encountering a particular type of interstitial opening may be related to this variable. Fig. 4 indicates the probability of encountering subquadrilateral and subtriangular packing as a function of the porosity of a closely sized spherical gravel. The separation of the rows of packing may be considered to be a single-valued function of the porosity; the resulting relationship is depicted in Fig. 5. It is believed that the number of unit cells encountered in the passage of a sand particle through a gravel screen is large enough to make such simple probability considerations of engineering value.

From a consideration of the geometry of subquadrilateral and subtriangular openings, the minimum number of particles required to form a bridge in the interstitial spaces of a gravel has been ascertained approximately. It was found that at the smaller ratios of gravel to sand diameters the relationships were discontinuous (Fig. 6). However, at the higher ratios the results were sufficiently continuous to permit the use of a simple linear relationship. It is probable that with gravels containing a range of particle sizes it will be desirable to consider the continuous relationship indicated by the dotted line in Fig. 6 as a reasonable approximation of the actual behavior even at the ratios for smaller diameters. The data presented in Fig. 6 indicate that the minimum number of particles required to form a bridge in a subquadrilateral opening is about eight times that required for a subtriangular opening involving the same size of gravel.

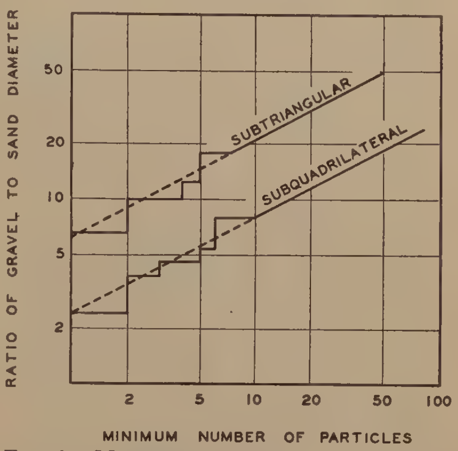

FIG. 6.—MINIMUM NUMBER OF PARTICLES TO FORM A BRIDGE.

The probability that a bridge will be formed as a result of the simultaneous appearance of the requisite number of particles at a particular opening decreases rapidly with an increase in the number of particles required. Experimental evidence indicates that this probability may be approximately expressed by the following equation, in which m represents the minimum number of particles required to form a bridge:

$$P = \left(\frac{1}{m}\right)^{m} \qquad [2]$$

As indicated in Fig. 6, the number of particles required to form a bridge varies markedly with the conditions of packing; therefore, on the basis of Eq. 2, the probability of the formation of a bridge would be expected to vary markedly. For example, with a ratio of 6 for the gravel-sand diameter, the probability of forming a bridge in a subtriangular opening is unity, while it is approximately 2.14×10^{-6} for a subquadrilateral opening.

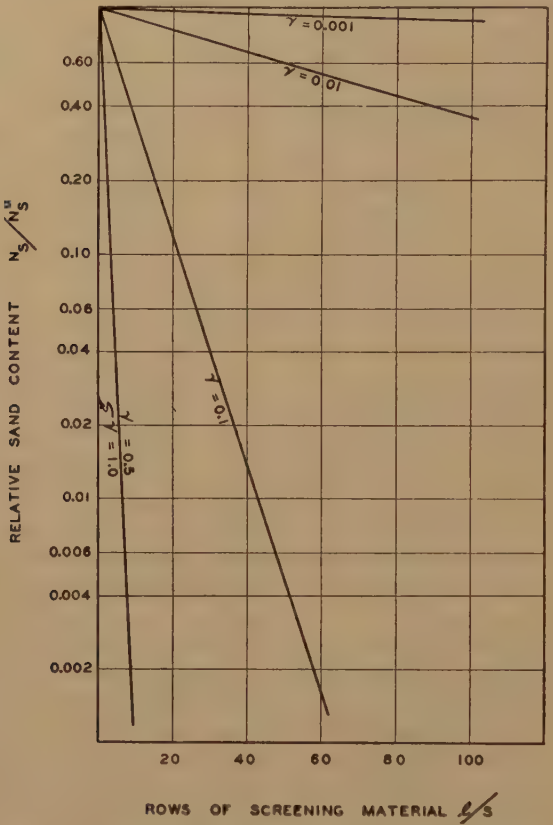

FIG. 7.—ESTIMATED SAND CONTENT OF GRAVEL SCREENS.

The probability P_t or P_q of encountering a subtriangular or a subquadrilateral opening in a particular row of packing has been depicted as a function of porosity in Fig. 4. Therefore, the probability that a bridge will be formed with a minimum number of particles in the average unit cell of a particular row may be approximated by the following equation, in which m_t and m_q represent the minimum number of particles required to form a bridge in subtriangular and subquadrilateral openings, respectively:

$$P = P_t\left(\frac{1}{m_t}\right)^{m_t} + P_q\left(\frac{1}{m_q}\right)^{m_q} \qquad [3]$$

Eq. 3 applies only to closely sized materials, which are not employed frequently in practice. However, it may be expanded to include material containing a range of particle sizes by rewriting in the following approximate form:

$$P = P_t \sum_{m=\min.}^{m=\infty} \left(\frac{n_m}{m_t}\right)^{m_t} + P_q \sum_{m=\min.}^{m=\infty} \left(\frac{n_m}{m_q}\right)^{m_q} = \gamma \qquad [4]$$

The quantity n_m in this equation is the weight fraction of material in the sand requiring less than m particles to form a bridge. In practice it is seldom necessary to carry the summation beyond a value of m greater than 5, since the series converges rapidly.

Eq. 4 indicates the probability of the formation of a bridge in an average unit cell in a particular row by particles of the sand in question. The fraction of the unit cells in a particular row of packing not forming bridges—i.e., those transporting sand—may be established in the following way:

$$F = 1 - \left[P_t \sum_{m=\min.}^{m=\infty} \left(\frac{n_m}{m_t}\right)^{m_t} + P_q \sum_{m=\min.}^{m=\infty} \left(\frac{n_m}{m_q}\right)^{m_q}\right] = 1 - \gamma \qquad [5]$$

If the lateral flow of the sand from the unit cell is neglected the influence of additional rows of material may be established easily. Flow through different rows must occur simultaneously, therefore it follows directly from probability considerations that in the gravel screen R rows from the sand-gravel interface the fraction of the unit cells that would be filled with sand may be expressed in the following way:

$$F_R = (1 - \gamma)^R \qquad [6]$$

If it is assumed still further that each bridge results in the same relative filling of the unit cell with sand, it is possible to relate the fraction of the cells filled to the sand content of the gravel screen. On this basis Eq. 6 may be rewritten as

$$n_s = \alpha(1 - \gamma)^R \qquad [7]$$

The constant α in Eq. 7 may be established from the sand content at the sand-gravel interface, for at the point where R is zero Eq. 7 becomes:

$$n_s^0 = \alpha \qquad [8]$$

A combination of Eqs. 7 and 8 yields the following relationship for the sand content of the gravel screen if the ratio of the distance from the sand-screen interface l to the spacing of the rows is substituted for R:

$$\log n_s = \log n_s^0 + \frac{l}{s} \log (1 - \gamma) \qquad [9]$$

This equation indicates that the logarithm of the sand concentration should decrease directly with the distance from the sand-gravel interface. It should be emphasized that in the derivation of Eq. 9 only the formation of bridges during the initial migration of the sand into the gravel screen has been taken into account. The influence of the movement of fluids through the screen with the attending breakdown of some bridges and the gradual formation of others has not been considered.

Eq. 7 permits an evaluation of the size of the sand and gravel and size distribution of the sand in terms of a single parameter. It is unlikely that the actual behavior of a particular combination of sand and gravel would be a single-valued function of this relatively simple parameter but it does take into account in at least a qualitative fashion the important influences. In Fig. 7 is depicted the estimated sand content of a gravel screen as a function of the distance from the sand-gravel interface for several values of γ. In this instance, since there is such a wide variation in γ, the negative logarithm of this quantity, $-\log \gamma$, has been employed. This figure indicates that the sand content of the gravel screen may be reduced a hundredfold with 40 rows of packing, at all values of $-\log\gamma$ less than unity. All of the information presented in Fig. 7 is based solely upon the geometry of the sand and gravel and no regard has been given to the flow conditions.

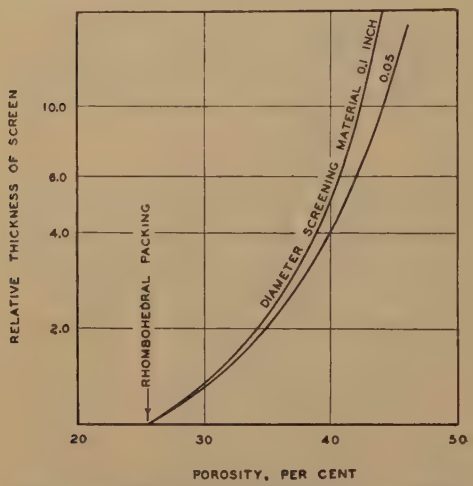

FIG. 8.—RELATION OF POROSITY TO EFFECTIVENESS OF GRAVEL SCREEN.

The influence of the packing of a gravel screen upon its effectiveness in preventing the migration of sand is presented in Fig. 8. In this diagram the relative thickness of a screen required to accomplish the same retention of an oil-field sand* is shown as a function of the porosity of the screen. A change in porosity of the gravel screen from 30 to 40 per cent causes more than a threefold increase in the thickness of the gravel screen necessary to accomplish the same result. This serves to indicate the importance of satisfactory packing in the effective placement of gravel screens.

EXPERIMENTAL RESULTS

It is impossible in the brief compass of a single paper to present the experimental results that were obtained. However, an outline of their nature and scope will permit some conclusions as to the applicability of these methods to practice. The experimental program had a twofold objective. The first purpose was to check the simple probability considerations that have been presented as to the influence of the geometry of the sand and gravel upon the migration of sand through a gravel screen. Secondly, it was desired to ascertain the effect of the flow of fluids upon this migration, since such influence could not be predicted even approximately.

The first part of the experimental program was restricted to the investigation of the movement of a homogeneous liquid through varying combinations of closely sized sand and gravels, of closely sized sands and lead or steel shot, and of naturally occurring oil-field sands and natural gravel, all under parallel flow conditions. The sand distribution in the gravel screen resulting from the passage of a homogeneous fluid through the working section under prescribed conditions was determined over a wide range of flow rates for each configuration of sand and screening material. A typical set of results with a naturally occurring sand and closely sized natural gravel is presented in Fig. 9. In this instance provision was made to prevent the migration of the sand from the downstream end of the working section but throughout the entire region where measurements were made the logarithm of the weight fraction of sand varied in a linear fashion with distance from the sand-gravel interface. The velocities indicated are average values for the gross cross-sectional area and should not be confused with the pore or point velocity sometimes considered. As a matter of interest, the value of $-\log\gamma$ corresponding to this combination of sand

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* This sand exhibited a permeability of 22 darcys at a porosity of 33.7 per cent and the cumulative weight per cent larger than a particular sieve opening was as follows: 0.0232 in., 0.46 per cent; 0.0164 in., 3.41 per cent; 0.0116 in., 14.76 per cent; 0.0082 in., 54.52 per cent; 0.0058 in., 82.07 per cent; 0.0041 in., 91.42 per cent; 0 0029 in., 95.2 per cent.

and gravel has been evaluated and the calculated sand distribution based upon Eq. 9 has been indicated by the dotted line.

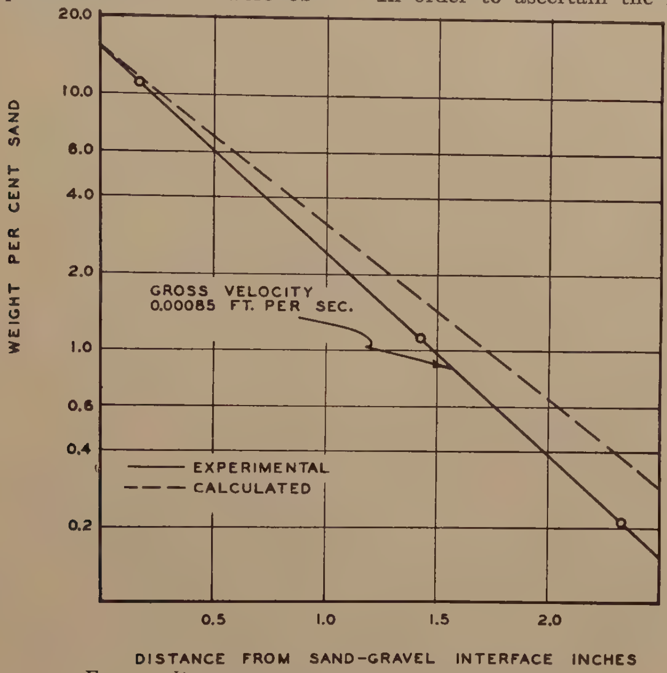

FIG. 9.—DISTRIBUTION OF SAND IN GRAVEL SCREEN.

Similar types of information were obtained in nearly one hundred sets of measurements except that combinations of sand and screening material resulting in large values of $-\log \gamma$ yielded nonlinear semilogarithmic relationships near the outlet of the working section as a result of the accumulation of sand that was not permitted to migrate from the section. In addition, 20 sets of measurements under radial flow conditions using a model gravel pack approximately 10.2 in. in diameter around a 4-in. liner with a penetration of 8 in. yielded the same general trends indicated in Fig. 9. It is believed, therefore, that the semilogarithmic sand-content distribution predicted on the basis of probability considerations is descriptive of actuality over a wide variety of conditions, However, the predictions based upon geometry alone are insufficient to estimate the effectiveness of a gravel screen, since the hydrodynamic conditions become of great importance in certain instances.

In order to ascertain the rate of sand migration through a gravel screen a series of measurements under radial flow conditions was made with arrangement for the removal of the sand after its migration through the gravel screen. The results obtained for a closely sized sand and three naturally occurring gravels are shown in Fig. 10. They indicate a gradual decrease of the sand concentration in the fluid leaving the section as the rate of flow is increased. This is followed by a rapid increase in concentration after a minimum value has been reached. The results obtained for an oil-field sand* and one of the same gravels have also been included in Fig. 10. This case likewise shows the pronounced minimum that apparently is typical of the behavior of a wide variety of sand-gravel combinations. This rather complex behavior may result from the simultaneous existence of two counteracting effects in the movement of sand through gravel screens. The first involves the building up of additional bridges by the continued passage of sand particles through the gravel screen; the second is the breakdown of these bridges by the larger dynamic forces acting on the sand particles as the velocity of fluid flow is increased. At low velocities this latter influence apparently is negligible but it is equal to the rate of formation of bridges at the minimum and rapidly overshadows the first influence at the higher velocities. It should be realized that although the concentration of sand in the liquid leaving the section goes through a minimum as the rate of flow is increased, the amount of sand transported per unit time steadily increases as the rate of flow is increased. In each case the corresponding value of $-\log \gamma$ has been indicated upon each of the curves and it shows a regular progression in accordance with the transportational characteristics of the combinations of sands and gravels presented here. The use of natural gravel has introduced a shape factor that was not taken into account in the earlier probability considerations.

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* The characteristics of this sand are described in a footnote on page 8.

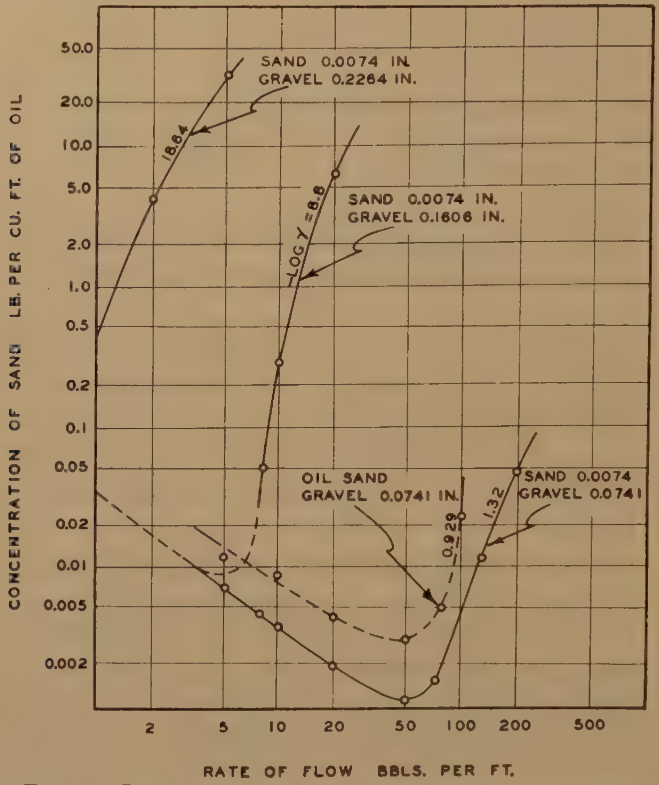

FIG. 10.—SAND CONCENTRATION IN OIL LEAVING GRAVEL SCREEN.

A series of 30 measurements involving viscosities from 70×10^{-6} to nearly 500×10^{-6} lb-sec. per square foot were made under parallel flow conditions employing both closely sized and naturally occurring sands with two sizes of lead shot and two sizes of closely sized natural gravels under uniform conditions of packing. The results were sufficient to indicate that the influence of the viscosity of the transporting fluid was significant. Nearly all of the results could be correlated within the experimental uncertainties by considering the product of the macroscopic velocity and the absolute viscosity of the fluid as a single parameter to describe the influence of the hydrodynamic conditions upon migration of sand particles through a gravel screen as a result of the movement of homogeneous fluids. This type of correlation is in accord with the laws of viscous flow since the forces acting upon individual particles would increase directly with both the microscopic velocity and the absolute viscosity. Therefore, if it is assumed that the flow pattern is independent of velocity, it is to be expected that an increase in the absolute viscosity would exert the same influence upon the movement of sand as would a corresponding relative increase in the macroscopic velocity if the influence of particle concentration in the flowing stream is neglected.

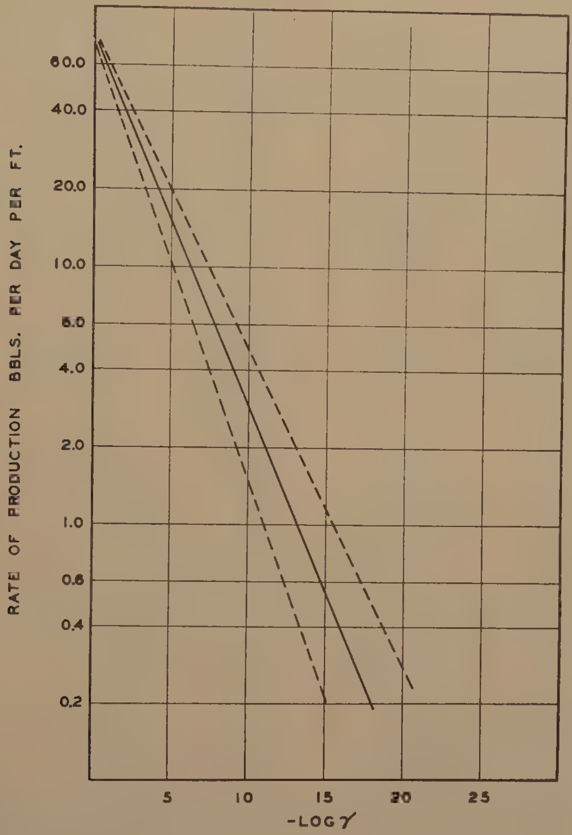

FIG. 11.—RATE OF PRODUCTION FOR THRESHOLD TRANSPORTATION.

Some experimental work was done under parallel flow conditions involving heterogeneous mixtures of liquid and gaseous hydrocarbons. The results included a rather wide variation in the relative quantities of gas and liquid phases present and covered the range of velocity likely to be encountered in practice. The influence of heterogeneous mixtures apparently is complex, especially with fine sands where surface forces become of comparable or greater magnitude than the macroscopic dynamic ones. However, in the great majority of cases the influence of the gas phase apparently was primarily related to the resulting increased velocity of the liquid phase. As a first approximation, until further experimental information is available, it may be assumed that the influence of the gas phase may be described by considering the heterogeneous fluid as homogeneous with a viscosity equal to that of the liquid phase and moving at a velocity based upon the specific volume of the heterogeneous fluid at the state in question and the total cross-sectional area. This is only a rough approximation, but it should be conservative and does permit the influence of a gas phase to be estimated.

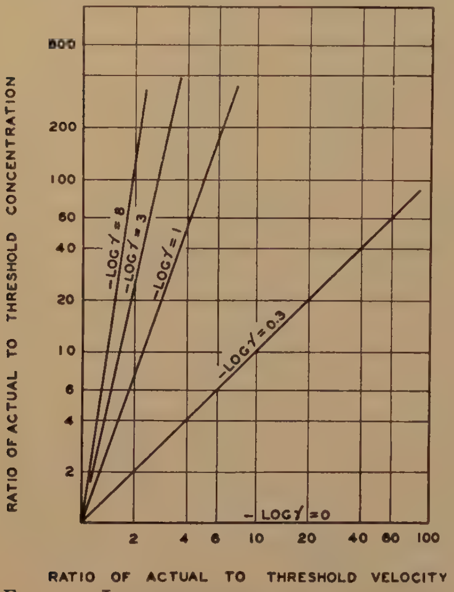

FIG. 12.—INFLUENCE OF VELOCITY UPON SAND CONCENTRATION.

CORRELATION OF RESULTS

From a consideration of the sand concentration in the fluids leaving gravel screens, it may be observed that the optimum operating conditions are close to the minimum value for the particular sand and gravel combination in question. If this situation is to be realized it becomes necessary to predict in advance of placement the range of flow rates likely to be encountered in future operations and to design a gravel screen to yield satisfactory results in this production interval. Furthermore, the influence of the viscosity of the oil and the relative quantities of liquid and gas phase under the conditions in question must be taken into account.

At the present state of knowledge the quantity $-\log \gamma$ as established from Eq. 4 is a satisfactory index of the influence of the geometry of the sand and gravel upon the migrational characteristics of the combination even though it neglects the influence of the shape of both the sand and gravel. On this basis the influence of the various pertinent hydrodynamic factors may be considered by use of a function of this parameter. In Fig. 11 is presented the rate of production of a homogeneous liquid per foot of penetration corresponding to the threshold transportation point (i.e., the point of minimum sand concentration in the fluid leaving the screen) as a function of $-\log \gamma$. The two dotted curves indicate the range in which experimental values were obtained for a gravel screen 10.2 in. in diameter around a liner 4 in. in diameter.

The behavior of gravel screens at velocities below the threshold point is not of great concern, since the quantity of material transported is small and probably the rate of transportation of sand would continue to decrease with time as the flow was prolonged at these relatively low rates. However, above this threshold point the situation is a dynamic one and the influence of velocity becomes of primary concern. In Fig. 12 is presented the variation in the sand concentration with fluid velocity above the threshold point for a series of values of $-\log \gamma$. These data indicate that the influence of velocity is much less pronounced for small values of this parameter. Although a very simple relationship is depicted in Fig. 12, other factors than those indicated undoubtedly influence the behavior; therefore the values shown should be considered more as indications of quantitative trends than as exact data.

The sand concentration in the fluid leaving the gravel screen at the threshold transportation point is influenced undoubtedly by many factors other than the relative geometric configuration of the sand and gravel that is described approximately by the parameter γ. However, this factor does exert an important influence and an estimation of this sand concentration as a function of $-\log\gamma$ is presented in Fig. 13. In this figure the limits of the experimental data have been indicated by the dotted curves while the more probable values have been presented as a full line. Although there is about a fourfold variation in the indicated sand concentration at the threshold point within the limits of the experimental measurements, the approximate relationship still has utility, since there is nearly a hundredfold variation in the concentration within the range of $-\log\gamma$ of industrial interest.

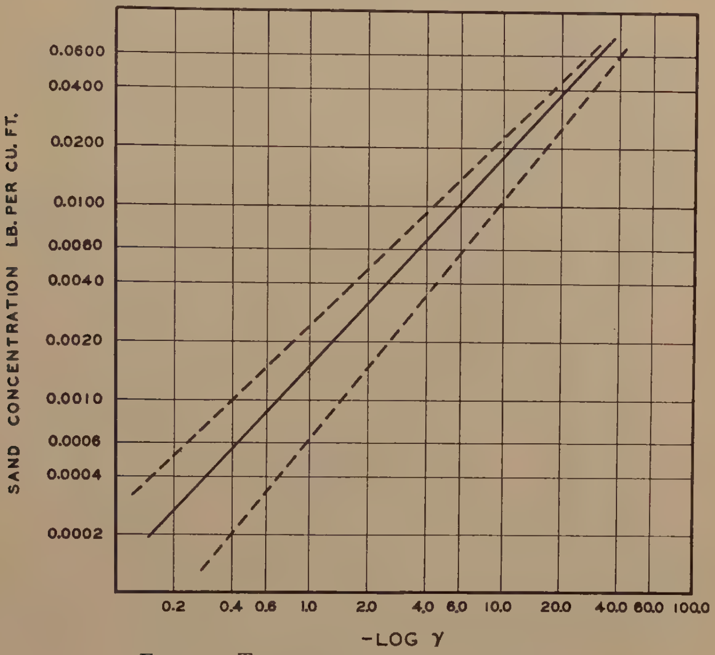

FIG. 13.—THRESHOLD SAND CONCENTRATION.

A combination of the data presented in the previous three figures yields the relationship portrayed in Fig. 14. In this diagram the maximum rate of production per foot of penetration that may be obtained with a homogeneous fluid without exceeding a given sand concentration at velocities above that corresponding to the threshold point is presented as a function of $-\log\gamma$. It should be realized that significant disagreements from these relationships should be expected, since the parameter γ does not take into account all of the factors pertaining to the geometric arrangement of the sand and gravel and these undoubtedly bear upon the rate of sand migration.

It is believed that the sand concentrations f leaving two similar gravel screens A and B differing only in thickness may be related roughly in the following fashion:

$$C = \frac{f_A}{(1-\gamma)^{l_A/s}} = \frac{f_B}{(1-\gamma)^{l_B/s}} \qquad [10]$$

Eq. 10 attempts to take into account only the influence of the thickness of the gravel screen. The relative geometry of the sand and gravel introduces an effect in this connection which is taken into account by the value of γ in the denominator of the expression. However, Eq. 10 will not yield results at all descriptive of actuality for materials exhibiting values of $-\log \gamma$ less than 0.5, but in such cases the concentration of sand within the fluid leaving the gravel screen is small enough to be unimportant. This expression should not be considered as indicative of the situations obtaining at sand concentrations above 2 lb. per cubic foot of fluid. Owing to the statistical nature of the background for Eq. 10, it is unlikely that satisfactory predictions of the relative behavior of gravel screens containing less than five rows of screening material can be obtained by its use.

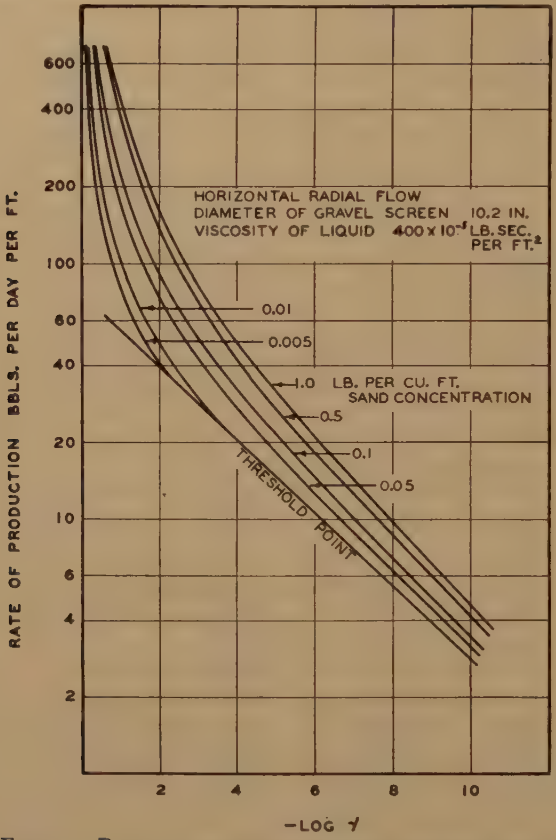

FIG. 14.—RATES OF PRODUCTION ABOVE THRESHOLD VALUE.

If the product of the viscosity and the velocity is a reasonable measure of the influence of the homogeneous fluid in inducing the migration of sand into the gravel screen, and if the use of the average velocity of the heterogeneous fluid mixture as a whole is a satisfactory measure of the influence of free gas, it is possible to consider both of these factors in a simple fashion. However, it should be realized that these quantities probably do not describe the actual situation with great accuracy but do indicate the trends to be expected.

The influence of these variables has been taken into account in the preparation of Fig. 15 by including them in the ordinate. Furthermore, the influence of the thickness of the gravel screen has been included by presenting curves for various values of the constant C in Eq. 10. On this basis it is possible to ascertain the value of γ necessary to yield a satisfactorily low sand concentration in the fluid entering the well for the conditions of operation expected.

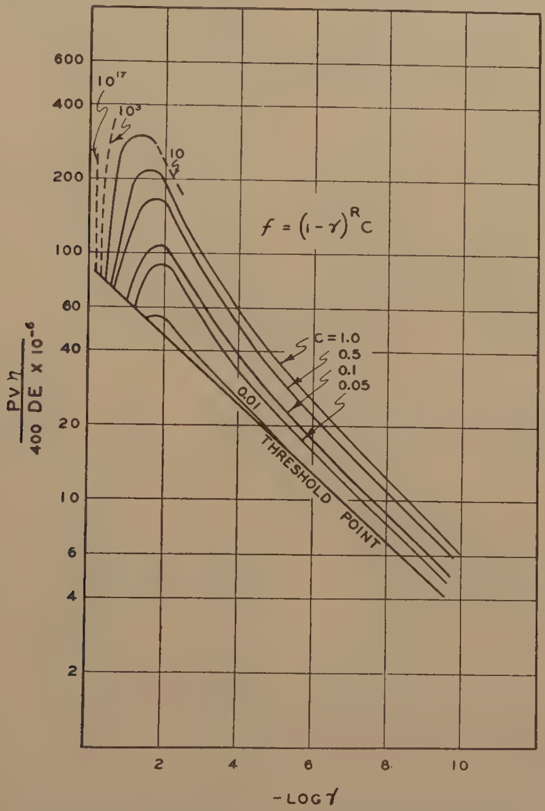

FIG. 15.—GENERAL BEHAVIOR OF GRAVEL SCREENS.

If it is assumed that the simple relationship of particle size and permeability portrayed in Fig. 1 persists to the smaller sizes of sand, it is possible to estimate the influence of gravel packing upon the productivity of a well as a function of γ. The information presented by the full curve in Fig. 1 may be described by the following relationship, which relates the diameter and the permeability of sands and gravels:

$$\log \frac{k_g}{k_s} = 1.9 \log \frac{d_g}{d_s} \qquad [11]$$

Upon the basis of a formation sand and a screening material, each composed only of closely sized particles, the relative productivity of a well may be computed as a function of γ from this expression. The results of such calculations are presented in Fig. 16, and indicate that there is little if any gain in the relative well production due to increasing the value of $-\log \gamma$ above 0.5. Furthermore, values of $-\log \gamma$ in the neighborhood of zero yield values of relative production only about 10 per cent below those for large values of this parameter corresponding to an exceedingly coarse gravel. The full curves in Fig. 16 are based upon closely sized sand, while naturally occurring sands that contain a wide range of particle sizes would more closely approximate the dotted curves presented in the figure. These curves indicate that an even smaller decrease in relative production would result from the use of gravel yielding a value of − log γ near zero. Such considerations indicate that gravels yielding values of − log γ greater than 0.5 may be employed without significant decrease in production as compared to that resulting from the use of a coarser gravel screen.

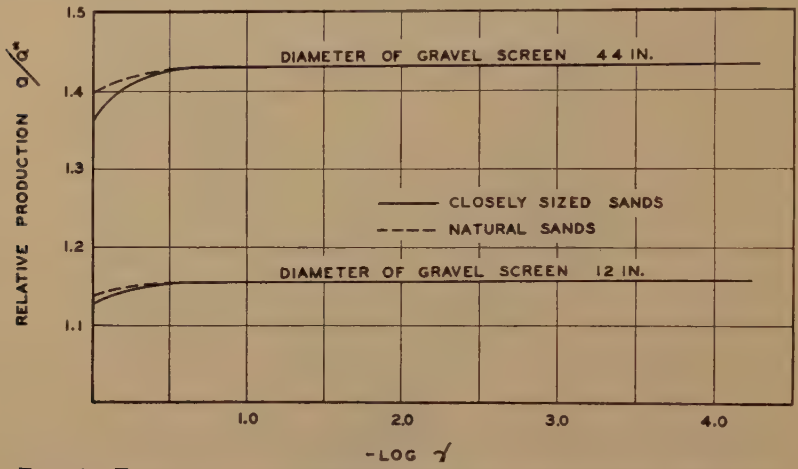

FIG. 16.—EFFECT OF RELATIVE SIZES OF SANDS AND GRAVELS UPON PRODUCTION.

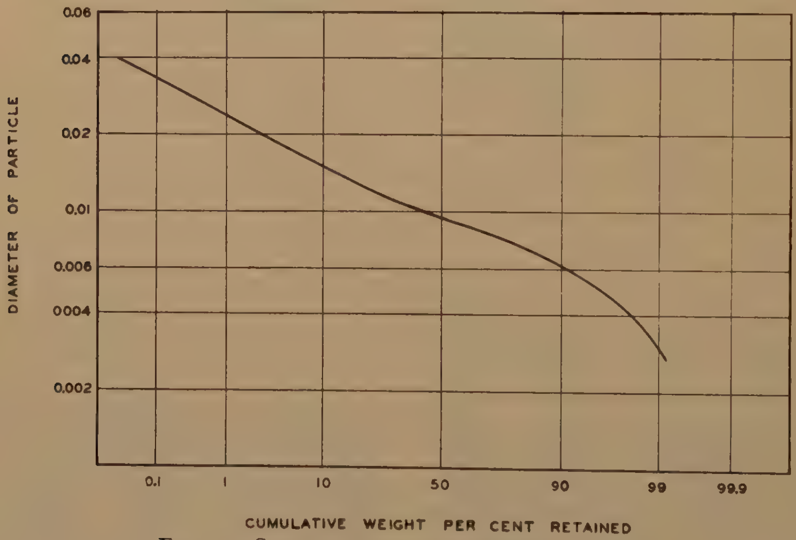

FIG. 17.—SIEVE ANALYSIS OF HYPOTHETICAL SAND.

DESIGN OF SUITABLE GRAVEL SCREENS

The following discussion relates to the illustrative application of the data heretofore presented to the estimation of the optimum diameter of gravel to be employed in a particular hypothetical situation. An attempt is made to include the influence of fluid velocity, viscosity, gas-oil ratio, formation pressure and temperature, size and condition of gravel packing and the nature of the formation sand.

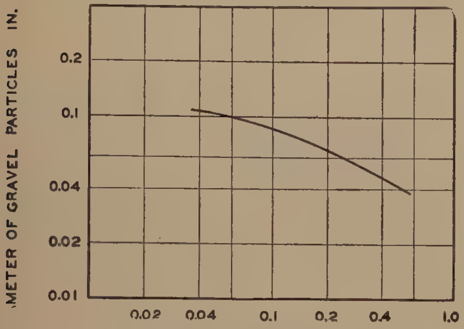

FIG. 18.—COMPUTED DIAMETER OF GRAVEL PARTICLES.

It will be considered that the objective of the gravel installation is to place a screen between the liner and the well bore throughout the production interval in such a manner that it will maintain the sand concentration less than 0.01 lb. per cubic foot in the liquid phase entering the liner. The assumed subsurface conditions for the fictitious well are recorded in a part of Table 1, while a sieve analysis of the sand obtained from the formation is presented in Fig. 17. Furthermore, it has been assumed that available formation-volume data[7] are applicable but the viscosity of the liquid phase under reservoir conditions has been taken at a somewhat higher value than that of the fluids employed in the experimental investigation from which the data were taken.

From the conditions and information presented in the upper part of Table 1, the ordinate of Fig. 15 was computed and is recorded in the lower part of the same table. In order to obtain a gravel screen that would yield a minimum sand concentration at the estimated rate of production, it follows from Fig. 15 that a value of $-\log \gamma$ of approximately 1.1 should be employed, which corresponds to a value of γ of approximately 0.1. The trial solution of Eq. 4, making use of the information presented in Fig. 6 and the sand analysis of Fig. 17, yielded the relationship between the diameter of the gravel particles and γ that is presented in Fig. 18. From this it follows that a value of γ of 0.1 corresponds in this instance to a gravel diameter of 0.085 in. On the basis of the available thickness of

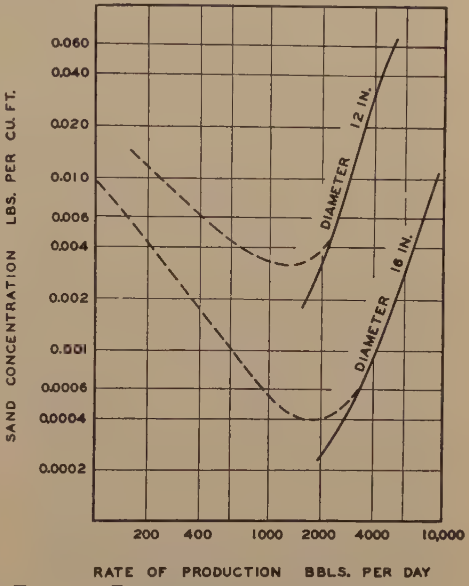

FIG. 19.—PREDICTED SAND CONCENTRATION IN OIL LEAVING GRAVEL SCREEN.

TABLE 1.—*Assumed Well Conditions*

Subsurface temperature, deg. F.	220
Subsurface pressure, lb. per sq. in.	2000
Gas-oil ratio, cu. ft. per bbl	730
Rate of production, bbl. per day	2000
Diameter of well bore, in	16
Diameter of liner, in	6
Effective penetration, ft	8.5
Porosity of gravel screen, per cent	40
Estimated subsurface properties of fluid:	
Formation volume	1.75
Viscosity of liquid phase, lb. sec. per sq. ft	80
Calculated quantities:	
$Pv\eta \times 10^6$ per 400 De	61.5
γ	0.1
Thickness of gravel screen l, in	5
Diameter of gravel particles d_g, in	0.084
Spacing of gravel screen S, in	0.0739
Rows of gravel packing, l/S	68
$(1 - \gamma)^{68}$	0.0012

the screen at an assumed porosity of 40 per cent, Fig. 5 indicates that it will be possible to obtain 68 rows of packing, which yields a value of $(1 - \gamma)$ of 0.0012. From this information it is possible to estimate the sand concentration in the fluid entering the well as a function of the rate of production from the data presented in Fig. 10. The results are indicated by the full curve in Fig. 19. The full curve has been terminated at the threshold transportation point, since these methods are not applicable at flow rates below this point. These data, together with experimental measurements at flow rates below the threshold value, such as are presented in a part of Fig. 10, indicate sand concentrations below 0.01 lb. per cu. ft. for rates of production between 100 and 9000 bbl. per day. The behavior below the threshold transportation point is somewhat uncertain but the estimated initial concentration has been indicated by the dotted curve. In general, experimental evidence indicates that there will be a gradual accumulation of sand in the interstices of the gravel screen, which will inhibit its further migration into the well, and the sand concentration at low rates of flow may be below the minimum value indicated in Fig. 19. Recourse to Fig. 7 indicates a sand content in the screen adjacent to the liner of approximately 0.0002 weight fraction. This low concentration of sand adjacent to the liner would be increased somewhat at the higher rates of oil production. The use of this fine gravel does not decrease the productivity of the well significantly below that which might be obtained if a much coarser gravel were utilized.

ACKNOWLEDGMENT

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NOMENCLATURE

b	Constant.
C	Parameter of Fig. 15, $f/(1 - \gamma)^R$.
D	Diameter of gravel screen, ft.
d_g	Diameter of gravel particle, in.
d_s	Diameter of sand particle, in.
E	Penetration of well—i.e., vertical distance exposed to sand, ft.
f	Sand concentration in fluid entering well, lb. per cu. ft.
F	Fraction of unit cells in particular row of packing remaining unbridged.
k_g	Permeability of gravel screen, darcys.
k_s	Permeability of sand body, darcys.
l	Distance from sand-screen interface, in.
m	Number of particles required to form a bridge.
m_q	Number of particles required to form a bridge in a subquadrilateral opening.
m_t	Number of particles required to form a bridge in a subtriangular opening.
n_m	Weight fraction of the sand requiring not more than m particles to form a bridge in a given opening.
n_s	Weight fraction of sand in screen.
n_s^0	Weight fraction of sand in screen at sand-screen interface.
P_q	Probability of encountering a subquadrilateral opening in entering a unit cell.
P_t	Probability of encountering a subtriangular opening in entering a unit cell.
Q	Oil production of well, bbl. per day.
Q^*	Oil production of well without gravel screen, bbl. per day.
R	Number of a row of packing particles in screen, starting from sand-gravel interface.
r_b	Radius of external boundary of formation, ft.
r_p	Radius of external boundary of gravel screen, ft.
r_w	Radius of internal boundary of gravel screen, ft.
S	Spacing of rows of packing in screen, in.
v	Formation volume.
γ	Probability of forming a bridge in a unit cell in a particular row of the screen.

Mechanism of Fluid Displacement in Sands

By S. E. Buckley and M. C. Leverett,* Members A.I.M.E.

(New York Meeting, February 1941)

The production of oil is accomplished as a result of its displacement from the reservoir by either gas or water, and the amount of oil recovery is limited by the extent to which the displacing gas or water accumulates. This paper describes the mechanism by which the displacement is effected and the advantages of water over gas as a displacing agent. In the light of the results of experimental observations of the flow of mixtures of oil and/or gas and/or water through sands, certain conclusions are drawn relative to the changing character of the displacement as depletion proceeds, and on the effects of the properties of the fluids and of producing conditions on the ultimate oil recovery.

Introduction

Crude oil has no inherent ability to expel itself from the pores of the reservoir rocks in which it is found; rather, it must be forcibly ejected or displaced by the accumulation of other fluids. Accordingly, a knowledge of the mechanism by which one fluid is displaced by another is essential to an understanding of the fundamental process by which oil is recovered.

The displacing fluids normally available are gas and water, either or both of which may exist originally associated with the oil in a potentially usable form or may be supplied to the reservoir from external sources. Gas is present in most oil reservoirs. If the quantity is relatively small, it may exist originally completely dissolved in the oil, but if the quantity exceeds that which may be held in solution by the oil at the prevailing pressure, the excess will be found in the free state. Most reservoir sands appear to contain some water,[1] and in the majority of fields the oil is trapped in the structure and held over water. In certain conditions the entrapping water may advance into the oil zone and displace the oil therefrom.

This paper describes in a qualitative manner some of the characteristics of the displacement of oil by either gas or water, with an attempt to elucidate somewhat the mechanism by which such displacement is effected.

Role of Dissolved Gas

When the pressure on an oil containing dissolved gas is reduced to the saturation or bubble-point pressure, gas escapes from solution and expands, imparting to the oil-gas mixture a high degree of expansibility and causing it to flow in the direction of reduced pressure. This expansibility has frequently been attributed to the oil; closer analysis, however, reveals that as gas escapes from solution the oil phase actually contracts. Hence, it is the accumulation and expansion of the liberated gas that supplies the propelling force for the oil.

It has been shown experimentally[2–5] that within certain limits a sand containing oil, gas and water will permit the simultaneous flow of all three; the readiness with which they may flow depends upon the characteristics of the sand, of each of the fluids, and upon the relative amounts of the fluids in the sand. Thus, in the initial stages of production by the mechanism of dissolved gas drive, the liberated gas is present in the sand in low concentration and is unable to

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* Humble Oil & Refining Co., Houston, Texas.

[1] References are at the end of the paper.

flow because of the low permeability of the sand to gas, with the result that the initial produced gas-oil ratio is substantially equal to the dissolved ratio. As the gas saturation in the sand increases, owing both to augmentation by the release of additional gas from the oil and by expansion of the previously liberated gas as a result of further decline in reservoir pressure, the permeability of the sand to oil rapidly decreases while the permeability to gas simultaneously increases, permitting the gas to flow along with the oil and escape. The period of low produced gas-oil ratio is therefore followed by a period of rapidly increasing ratio during which a major part of the original store of dissolved gas is dissipated. As exhaustion of the reservoir proceeds, the permeability of the sand to gas continues to increase and the permeability to oil to decrease; however, in the final stages of depletion the decline in reservoir pressure offsets the changes in permeability by virtue of the fact that whereas the volume of gas flowing in the sand per unit of oil flowing is still increasing continuously, the actual weight or amount of gas contained in unit volume is decreasing, with the result that the produced gas-oil ratio, with the gas volume corrected to a standard base pressure, passes through a maximum and thereafter declines.

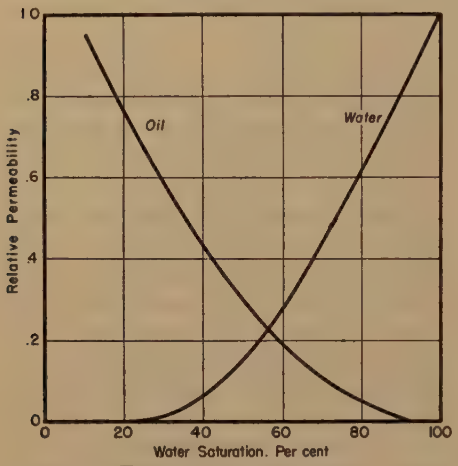

Fig. 1.—Effect of saturation on relative permeabilities to water and oil in unconsolidated sands.

Production from a reservoir by the mechanism of dissolved-gas drive alone is thus characterized by low initial gas-oil ratio, followed by rapid increase to a maximum ratio, with a declining ratio as the supply of gas and the pressure approach exhaustion. This mechanism is fundamentally inefficient and the amount of oil that can be recovered thereby is seriously limited. This inefficiency arises from the following conditions:

1. The oil saturation decreases and the gas saturation increases simultaneously and more or less uniformly throughout the reservoir.

2. The displacing fluid is thus able to compete for production on an equal basis with the oil.

3. Since the gas is disseminated throughout the oil sand, it cannot be excluded by mechanical means from the oil-producing wells.

It is thus a natural and unavoidable result that by this mechanism the gas is completely dissipated, leaving in the reservoir no force other than gravity to expel the remaining oil. Production by gravity drainage alone, although in some reservoirs it may in time lead to substantial oil recovery, is usually exceedingly slow.

Dynamics of Displacement by Free Gas or by Water

Under certain conditions, particularly at very low rates of production and in highly permeable sands, vertical segregation brought about by gravitational forces may be superimposed upon the dissolved-gas drive mechanism, leading to the formation in the upper part of a structure of "free gas" zones, which in reality are zones of higher gas saturation and lower oil saturation than exist in the lower part of the reservoir. Such segregation leads to the possibility of some degree of mechanical selection in production.

If the areas of high gas saturation can be made to increase in extent through continued segregation or by the return of produced gas to the reservoir, and controlled by production of only the wells low on structure, a displacement of oil in the reservoir may be effected during which the area of high gas saturation will encroach on the area of high oil saturation until the latter becomes too small to permit effective control of the gas production. During the final stages of production, the gas again will be dissipated, but the deferment of such dissipation and the increased gas accumulation brought about thereby will increase correspondingly the quantity of oil produced.

The mechanism by which the area of high gas saturation invades the area of high oil saturation is very similar to that by which water encroaches into and displaces oil from a sand. In either case the displacing fluid moves from a region of high saturation into one of lower saturation and in so doing removes oil and converts the invaded region to one higher in saturation of the displacing fluid. It should be borne continuously in mind that whether the displacing fluid be gas or water it does not behave as a piston ejecting oil from the pores and occupying the space vacated, but that in all cases both the oil and the displacing fluid flow together and simultaneously through the same pores. Displacement, therefore, can never be complete. The actual amount of oil displacement during the process depends upon the relative ease with which the two fluids can move. As mentioned previously, the readiness with which a fluid flows through a sand increases with its saturation in the sand. Hence, as displacement begins, the oil saturation in the sand may be high and the saturation of the displacing fluid may be low; oil will flow readily and the displacing fluid to a small extent only, if at all. At this stage, the displacing fluid will be almost 100 per cent effective. As displacement proceeds the permeability of the sand to oil will continuously decrease and the permeability to the displacing fluid will continuously increase, until during the latter part of the process large volumes of displacing fluid will effect removal of only a slight amount of additional oil. The oil recovery obviously is determined by the availability of the displacing fluid and by its net accumulation during the displacement process.

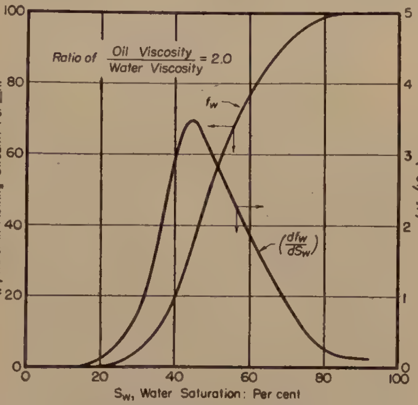

FIG. 2.—f_w AND df_w/dS_w AS FUNCTION OF S_w FOR UNCONSOLIDATED SAND.

At this stage in the process, the net rate of accumulation of the displacing fluid, which is equal to the net oil displacement, is proportional to the difference between the rate at which the displacing fluid enters the sand and that at which it leaves. If we confine our attention to unidirectional flow through a small element of sand within a continuous sand body, the foregoing may be expressed algebraically by a material balance equation, as follows:

$$\left(\frac{\partial S_D}{\partial \theta}\right)_u = -\frac{q_T}{\phi A}\left(\frac{\partial f_D}{\partial u}\right)_\theta \qquad [1]$$

where S_D = saturation of displacing fluid
θ = time
u = distance along path of flow
q_T = total rate of flow through section

ϕ = porosity
A = cross-sectional area
f_D = fraction of flowing stream comprising displacing fluid

This equation may be transformed to

$$\left(\frac{\partial u}{\partial \theta}\right)_{S_D} = \frac{q_T}{\phi A}\left(\frac{\partial f_D}{\partial S_D}\right)_\theta \qquad [2]$$

which states that the rate of advance of a plane that has a certain fixed saturation is proportional to the change in composition of the flowing stream caused by a small change in the saturation of the displacing fluid.

If, for simplicity, we neglect for the time being effects due to gravity and to capillary pressure differences, f_D, the fraction of displacing fluid in the flowing stream at any point, is related to the properties of the system by the equation

$$f_D = \frac{1}{1 + \frac{K_0\mu_D}{K_D\mu_0}} \qquad [3]$$

where K_0 and K_D are the permeabilities of the sand to oil and to the displacing fluid, and μ_0 and μ_D are the viscosities of the two, respectively. Since the relations between the relative permeabilities of a sand to oil, gas, and water and the respective saturations have been determined experimentally for several sands, including a consolidated sandstone,[2–5] it is possible from equation 3 and the experimentally determined permeability ratios to derive the relation between f_D and S_D and thence between $\frac{\partial f_D}{\partial S_D}$ and S_D for a given system. In the absence of capillary and gravitational effects, f_D for a given sand and fluids varies only slightly with factors other than S_D, and it may be assumed that under these conditions $\frac{\partial f_D}{\partial S_D}$ is also uniquely related to S_D, being constant for fixed S_D. Referring back to equation 2, it may be seen that a plane at which the saturation is S_D moves along the path of flow at a constant velocity equal to $\frac{q_T}{\phi A}\frac{df_D}{dS_D}$. The basic equation relating position along the path of flow, saturation, and time then may be written

$$\Delta u = \frac{q_T}{\phi A}\left(\frac{df_D}{dS_D}\right)\Delta\theta \qquad [4]$$

or, in terms of Q_T, the total amount of displacing fluid entering the system:

$$\Delta u = \frac{Q_T}{\phi A}\frac{df_D}{dS_D} \qquad [5]$$

As an example of the application of this equation to the qualitative determination of the course of a displacement, a typical example will be worked out for the saturation distributions during the flooding of a sand section by water.

Fig. 1 shows the experimentally determined relation between K_0, K_w, and S_w for a typical unconsolidated sand containing only water and oil.

Fig. 2 shows the relation between f_w and S_w and between $\frac{df_w}{dS_w}$ and S_w assuming the ratio of the viscosity of the oil to that of water to be 2.0.

Fig. 3 shows the initial vertical distribution of water and oil in the sand, calculated from experimentally determined relations between capillary pressure and saturation and assuming the following: sand permeability, 1 darcy; sand porosity, 25 per cent; interfacial tension $w - o$, 35 dynes per cm.; density difference $w - o$, 0.3 gm. per cubic centimeter.

The water saturation at any point in the sand after the entry of a quantity of water Q_1 is obtained graphically by laying off at any saturation S_{w_1} on the curve of saturation vs. distance shown in Fig. 3 a line a parallel to the distance, u, axis and equal in length to $\frac{Q_T}{A\phi}\frac{df_{w1}}{dS_{w1}}$. The ends of a succession of such lines are then joined by a smooth curve representing the new curve for water saturation vs. distance. The construction of the new curve is illustrated in Fig. 3.

The new computed curve is S-shaped and is triple-valued over a portion of its length, obviously a physical impossibility. The correct interpretation is that a portion of the curve is imaginary and that the real saturation-distance curve is discontinuous. The imaginary part of the curve is dotted in Fig. 3 and the real distribution curve is shown by the solid line labeled Q_1, discontinuous at u_1. The position of the plane u_1 is determined by a material balance, the shaded area between the original and the new saturation curve being equal to $\frac{Q_1}{A}$.

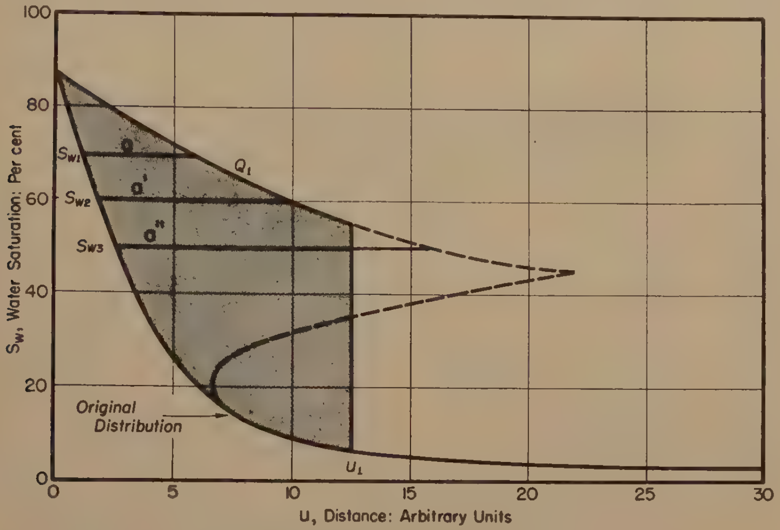

FIG. 3.—CALCULATION OF SATURATION HISTORY DURING WATER FLOOD.

In any actual displacement of oil from sand by gas or water, no such saturation discontinuity as that indicated in Fig. 3 can exist in a uniform sand. The capillary forces arising from the interfacial tension between oil and the displacing fluid and the curvature of the interfaces in the sand tend in all cases to maintain uniform saturation throughout any continuous homogeneous sand body. The degree of equalization obtained depends upon the combined effects of the capillary pressure gradient, gravitational pressure gradient, and the impressed pressure gradient. Although in the regions of gradual transition of saturation with distance the capillary pressure gradient may be small in comparison to the other forces, at any saturation discontinuity the capillary pressure gradient would become exceedingly large, with the result that the plane of saturation discontinuity would be converted into a zone of more gradual transition in saturation, the width of the zone depending for a given system primarily upon the rate of displacement. For many cases a slight rounding off of the corners of the curve illustrated in Fig. 3 will represent a reasonable approximation to the conditions encountered in practice.

INITIAL AND SUBORDINATE PHASES OF DISPLACEMENT

Fig. 3 indicates that at a plane in the sand some distance away from the point of entry of the water, no substantial change in the water saturation results as the water first advances. Then a very rapid rise in water saturation takes place as the transition zone reaches and passes the plane. This period of rapid increase of water saturation may be considered the initial phase of the displacement. During this phase the displacement is quite effective; most of the water reaching the plane remains in the sand, ejecting oil. Following this period further increase in water saturation is much more gradual. This final period of gradual water accumulation may be termed the subordinate phase of the displacement. During this period water flows more readily than does the oil, so that relatively large volumes of water flowing through the sand effect the removal of only small and continuously decreasing volumes of oil.

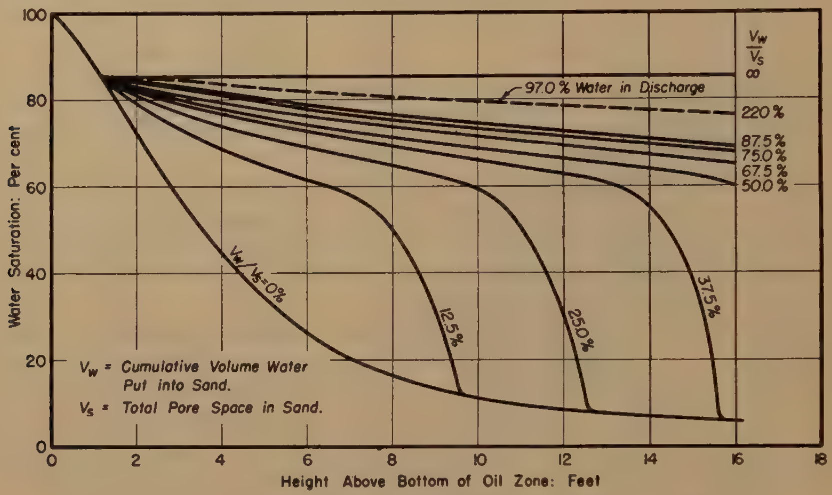

FIG. 4.—SATURATION HISTORY OF OIL-BEARING SAND UNDER WATER FLOOD.

The course of a typical water flood is illustrated in Fig. 4, in which curves are shown for the water saturation-distance distribution at successive periods during the displacement. The gradual increase in water saturation and decrease in oil saturation during the subordinate phase of the displacement may be seen from the progressively increasing volumes of water required to effect minor saturation changes during the later stages. As the ratio of the oil permeability of the sand to the water permeability approaches zero with decreasing oil saturation, flow of oil eventually ceases and the oil that remains is unrecoverable. The quantity of unrecoverable oil has been referred to as the residual oil and is a useful index to the recovery efficiency.[6]

CONDITIONS AFFECTING RELATIVE MAGNITUDES OF INITIAL AND SUBORDINATE PHASES OF DISPLACEMENT

Viscosity.—Since the rate of advance of a plane of given water saturation is directly proportional to $\frac{df_w}{dS_w}$, and since f_w is related to the ratio of the viscosity of oil to that of water as well as to the relative permeabilities of the sand to oil and to water, the course of the curves of water saturation vs. distance is influenced by the oil viscosity. The more viscous the oil, the less readily it flows under a given pressure gradient. Increased oil viscosity therefore results in the attainment of a lower water saturation during the initial phase of the displacement as well as a more gradual approach to the residual oil saturation during the subordinate phase of the displacement. The calculated effect of the ratio of the viscosity of the oil to that of water on the water saturation reached during the initial phase of the displacement in a typical sand is shown in Fig. 5.

The effect of viscosity is best illustrated by the differences between displacement by free gas, such as occurs with an expanding gas cap or as a result of gas injection in gas-drive operations, and that by water drive. In Fig. 6 are shown the gas saturation-distance curves after the admission of various amounts of gas, calculated for a typical sand assuming a viscosity ratio of gas to oil of 0.009. During the initial phase of the displacement the gas saturation attains a value of only about 15 per cent of the pore space as contrasted to a comparable water saturation of about 60 per cent for an oil of the same viscosity.

Effect of Initial Fluid Saturation.—If before invasion by the displacing fluid the saturation of the displacing fluid in the sand exceeds that which would be obtained during the initial phase of the displacement, this phase will be absent and only the subordinate phase will occur. Such a condition would be encountered in a water-drive operation where the original or connate-water content of the sand is excessive and in practice is most likely to be met in tight sands, with viscous oils, or in thin oil sands immediately overlying water. It is not possible to produce oil free from water in the part of the sand where this condition prevails.

In gas-drive operations such a condition is found if prior to the injection of gas the reservoir pressure has declined to such an extent as to permit the accumulation of gas released from solution in the oil to an amount exceeding the saturation that would be attained during the initial phase of the displacement. Such a condition is almost invariably encountered in gas-drive operations inaugurated late in the life of a field or after primary exhaustion. Fig. 7 illustrates the variations in produced gas-oil ratio that would occur under: (*a*) displacement by gas at the original reservoir pressure, and (*b*) displacement by gas after appreciable decline in reservoir pressure. In the first instance the produced gas-oil ratio remains equal to that dissolved in the oil until the gas front reaches a producing well, when a sudden increase in the ratio occurs during the initial phase of the displacement, followed thereafter by a continuous increase in ratio. In the second instance the produced gas-oil ratio follows the typical course of production by dissolved-gas drive prior to the start of the gas injection. The injection of gas halts the natural increase in ratio until such time as the injected gas reaches the producing wells, when the gas-oil ratio begins to increase continuously at an accelerating rate. The initial phase is absent and only the subordinate phase of the displacement occurs.

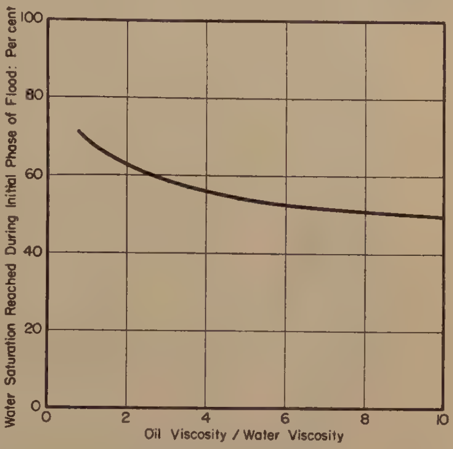

FIG. 5.—EFFECT OF OIL VISCOSITY ON EFFICIENCY OF INITIAL PHASE OF WATER FLOOD.

No generalizations are possible concerning the advantages of either method of operation over the other; however, for any given set of conditions it should be possible to determine the relationship between gas-oil ratio, pressure, and production with sufficient accuracy to determine an economically sound program of operation.

Capillary and Gravitational Effects.—Capillary forces tend to oppose the formation of saturation discontinuities in a

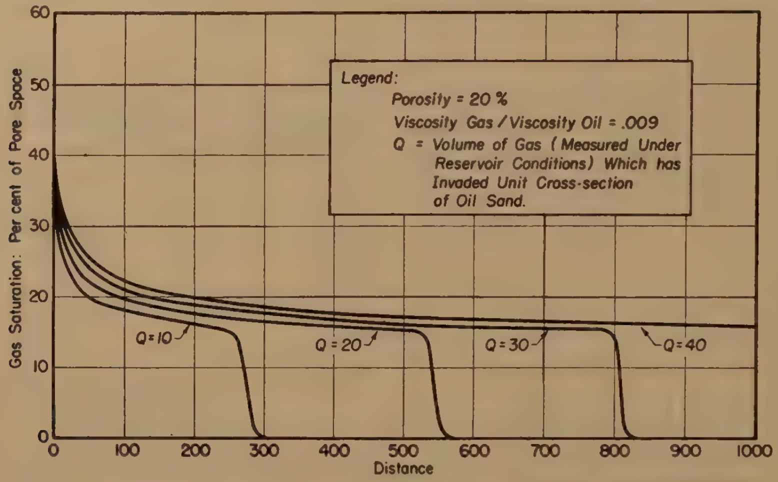

FIG. 6.—SATURATION HISTORY OF OIL-BEARING SAND UNDER GAS DISPLACEMENT.

homogeneous sand, while gravitational forces tend to promote complete vertical segregation of oil, gas, and water. Thus in any reservoir in which water is advancing upward or gas downward to displace oil, the capillary and gravitational effects oppose each other and tend somewhat to cancel. At high rates of displacement the frictional forces may exceed both, with the result that their effects are obscured and the flow is regulated primarily by the relative permeabilities and viscosities as was indicated in equation 3. At extremely low displacement rates, however, the frictional forces may be negligible and the balance between capillary and gravitational forces control the saturation distribution. In this case the vertical distribution in the reservoir may remain substantially similar to that obtained under static conditions, in which the capillary pressure is constant at a given depth and the entire reservoir is in capillary-gravitational equilibrium.[7]

CAPILLARY EFFECTS IN HETEROGENEOUS SANDS

The effects of capillary forces are most noticeable in the production by water drive of reservoirs containing intercommunicating sands of variable permeability. All degrees of heterogeneity are encountered in natural reservoirs, ranging from more or less definite sand layers, each relatively uniform within itself but different in texture and permeability from adjacent beds, to conditions such as more permeable or less permeable zones or lenses within a continuous sand. These lenses may be so small and so numerous as to constitute, together with the enclosing sand, a bed of very irregular properties, or they may be large and fairly uniform within themselves. Since the recovery from the reservoir as a whole depends upon the efficiency with which all parts of the sand are flushed, a study of the mechanism by which water penetrates and floods irregular sand bodies is extremely important.

Prior to production the reservoir may be assumed to be in capillary equilibrium; i.e., at the same horizontal level the capillary pressure is the same in all sands and the capillary pressure and gravity are balanced vertically. At equilibrium the water saturation throughout the reservoir is not uniform, but at the same level is greater in the finer, less permeable sands. When water advances into the reservoir as a result of oil production, the level of zero capillary pressure rises, creating a tendency for the water saturation throughout the reservoir to increase in order to attain a new balance between capillary pressure and gravity. The relationship between capillary pressure, water saturation, and permeability is such that the tendency is for the fine sands always to maintain higher water saturations at equilibrium than the adjacent coarse sands at the same level.

The complexity of natural reservoirs prohibits the formulation of any single quantitative expression relating over-all flushing efficiency to the rate of production, or to any of the other pertinent variables. The factors involved, however, may be illustrated in a qualitative fashion by considering the behavior of a small lens of tight, fine sand embedded in a coarse, more permeable sand at some distance above the original water table. If the rate of production is such that the water table rises slowly enough to permit the maintenance of capillary equilibrium, the water saturation in the coarse sand will gradually increase

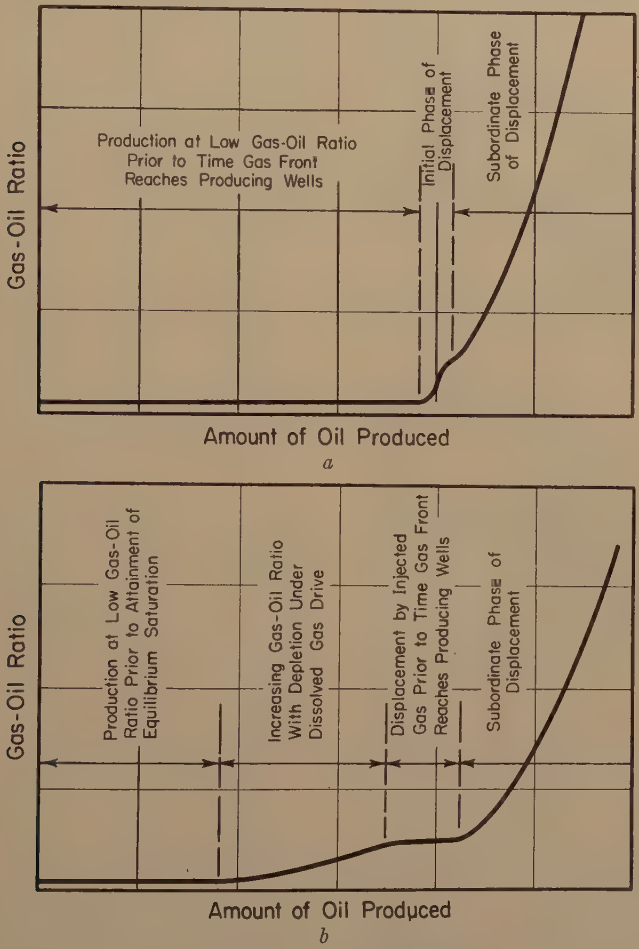

FIG. 7.—VARIATIONS IN GAS-OIL RATIO DURING DISPLACEMENT OF OIL BY GAS.
a. Displacement at high pressure.
b. Displacement at low pressure.

simultaneously with the rise in the water table. As the water saturation in the adjacent coarse sand increases, the tight lens will imbibe water and expel oil, both by absorbing water at the bottom and expelling oil at the top and by counterflow of water and oil over the entire surface of the lens, tending always to maintain a higher water saturation than that reached by the surrounding coarse sand. Thus the tight sand will at all times be more completely flushed than the coarse sand and will become depleted while oil is still flowing in the surrounding sand.

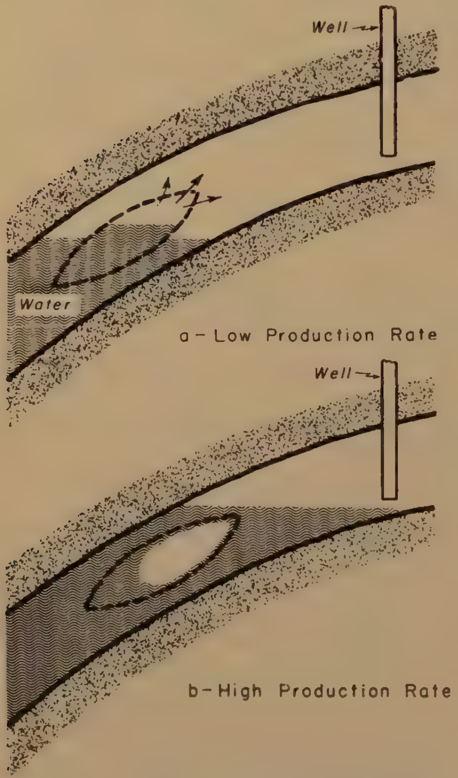

FIG. 8.—EFFECT OF PRODUCTION RATE ON FLOODING OF OIL BY WATER FROM A LOW-PERMEABILITY LENS.

The higher the rate of production the more nearly the advancing water table assumes the sharp front described in the first part of this paper. Instead of a continuous increase in water saturation, no sensible increase takes place until just before the advancing water front reaches a given position, whereupon the water saturation rises rapidly during the initial phase of the displacement. Under such conditions the tight lens just considered will have no opportunity to imbibe water from the beginning of production, but will become somewhat suddenly surrounded by a zone of high water saturation when it is reached by the flood. Oil may then escape from the tight sand exclusively by counterflow of water and oil between the two sands, an exchange that is slow at best. Furthermore, any oil that escapes from the tight lens may enter the surrounding coarse sand so slowly and into a region of such high water saturation that this oil will not be recovered. Thus, although in time the lens undoubtedly will expel its oil and become substantially water-saturated, as a practical matter it may be considered that the oil was trapped and lost. The conditions under both low and high displacement rates are illustrated in Fig. 8. For this particular situation, it is evident that the slower the rate of water advance, the higher the recovery.

It is readily apparent that in any natural reservoir composed of heterogeneous sands the over-all recovery is related to the rate of advance of the water. The magnitude of the effect depends upon the degree and nature of the irregularities of the sand and upon the viscosity of the oil.

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Control of Filtration Characteristics of Salt-water Muds

By G. R. Gray,* Member A.I.M.E., J. L. Foster* and T. S. Chapman*

(New York Meeting, February 1941)

The wall-building properties of salt-water drilling muds can be improved markedly by the addition of: (1) natural gums, such as tragacanth, karaya, and ghatti; (2) seaweeds, such as Irish moss; or (3) gelatinized starch. Results of laboratory tests have been confirmed by field trials. For drilling operations in which the mud becomes contaminated by salt, either through penetrating salt-bearing rocks or by addition of sea water to the mud, the added cost resulting from the use of one of the substances listed above is more than offset by freedom from stuck drill pipe and ease in running casing.

Introduction

It has been recognized for many years that oil production might be seriously hampered by infiltration of water from the drilling mud.[1-4] As knowledge of the mechanism of the wall-building process advanced, methods were developed for evaluating the filtration characteristics of muds.[5-11]

The wall-building properties of fresh-water muds are commonly regulated by the addition of bentonitic clays, or of agents to promote the dispersion of the natural mud solids. When strata bearing soluble salts are encountered in the course of drilling, the salts are incorporated in the mud; the clay solids are flocculated and water loss is increased tremendously. Methods generally used in controlling filtration of fresh-water muds are no longer applicable.

The problem of reducing water loss from salt-water muds is not confined to any particular area, but is acute in parts of West Texas. Salt beds several hundred feet thick must be penetrated before the oil-bearing formation is reached. Since the formation drilled does not provide mud-making material, it is necessary to use large quantities of commercial clays, and even the best commercial clay does not afford relief from the problem of high filtration.

A laboratory study has been made of methods of improving the filtration characteristics of salt-water muds, and some of the methods have been used in field practice.

Laboratory Investigations

Procedure

Inasmuch as the immediate object of the investigation was the development of means of improving the wall-building properties of muds used in West Texas, an attempt was made to employ muds in the laboratory study comparable to those in field use. Samples of muds used in drilling the producing formations in six wells were secured. The properties of these samples are summarized in Table 1, which lists the densities, viscosities, filtrations, and analyses of the filtrates for calcium, chloride, and sulphate. Viscosity was measured in the Stormer viscosimeter at 600 r.p.m. Water loss was determined at 80°F. with the Baroid low-pressure wall-building tester[8] at a pressure of 100 lb. per sq. in. Filtration rates are considerably higher than those of usual fresh-water muds, which amount to about 20 c.c. in 30 min. Water loss was so rapid in samples 4, 5 and 6 that filtration was complete in less than 10 min. and the values for 30 min. were extrapolated from the rates at shorter

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[1] References are at the end of the paper.

times. Inquiry revealed that in accordance with common practice lime had been added in the preparation of muds 4, 5 and 6.[1] Subsequent tests showed that definite injury to wall-building properties of mud resulted from the addition of as little as 0.1 per cent of lime.

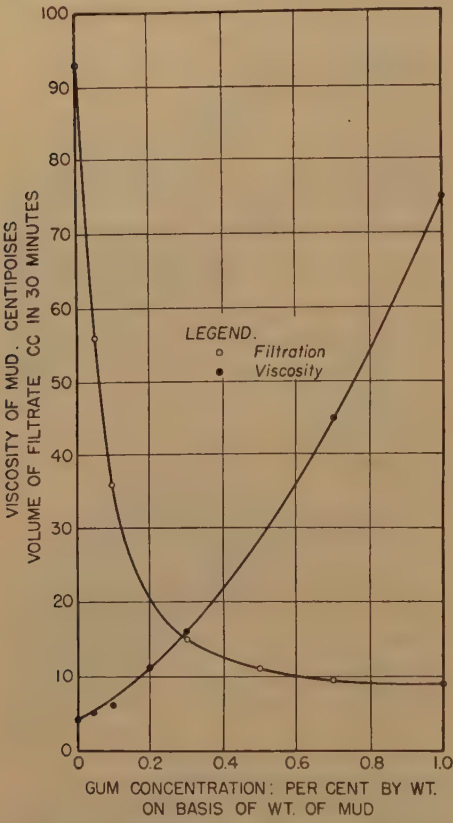


FIG. 1.—EFFECT OF TRAGACANTH GUM ON FILTRATION AND VISCOSITY OF 20 PER CENT SHAFTER LAKE CLAY IN SALT SOLUTION.

It was inconvenient to secure field muds for all laboratory tests. Muds were prepared in the laboratory as needed from commercial surface clays available in West Texas. The salt solution used in many of the tests contained 80 grams of sodium chloride, 12 grams of calcium chloride, and 2 grams of calcium sulphate per liter. This composition was approximately that of the average of a number of field water samples.

Other tests were made using a saturated solution of sodium chloride. Muds were prepared by dispersing with a high-speed stirrer 60 grams of clay in 240 grams of salt solution to which the agent under investigation was added. After they had stood overnight, samples were stirred thoroughly, the viscosity was measured, and the mud was transferred to the wall-building tester. The filtration was expressed as the cumulative volume of filtrate at the end of 30 min., corrected for drainage.

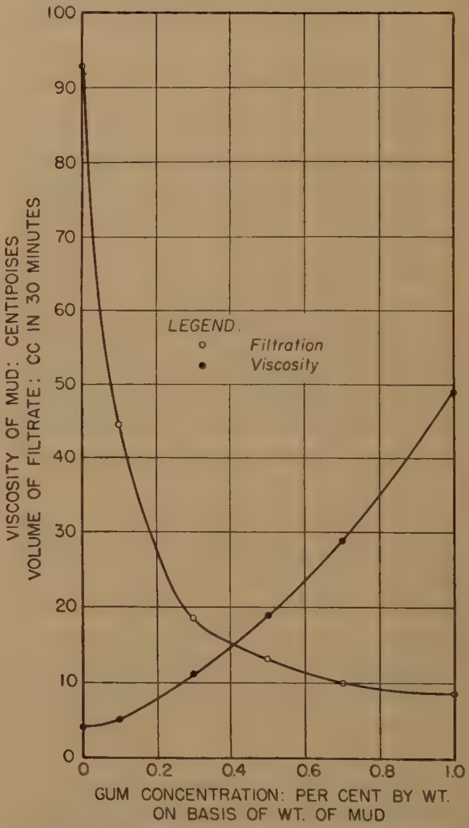


FIG. 2.—EFFECT OF KARAYA GUM ON FILTRATION AND VISCOSITY OF 20 PER CENT SHAFTER LAKE CLAY IN SALT SOLUTION.

Addition of Gum

One of the first substances that brought about a marked improvement in the wall-building properties of salt-water muds was tragacanth gum. Other natural gums that swell in water were also found to be effective. Among these were arabic, ghatti, karaya, and locust bean. Gums consist essentially of carbon, hydrogen and oxygen, with a small amount of mineral matter. They are made up of sugars chemically united with an acid nucleus. Natural gums occur as exudates on the trunks and stems and in the kernels of various trees and shrubs. The natural products are sorted on the basis of trade standards and are milled to produce a variety of grades. Only the least expensive grades were investigated for use in drilling muds.

Laboratory tests were made on many samples of gums in a variety of salt-water muds. The results shown in Figs. 1, 2 and 3 are typical. Fig. 1 shows the effect of tragacanth gum on the viscosity and filtration of a 20 per cent suspension of Shafter Lake clay in a salt solution of the composition given above. The water loss decreases rapidly with small additions of gum from an original value of 93 c.c. in 30 min. to 19 c.c. after the addition of 0.2 per cent of tragacanth gum. Mud containing 0.5 per cent of gum has a water loss of only 11 c.c. But little further reduction is secured on increasing the concentration to 1 per cent. Viscosity of the mud increases continuously from 4 to 75 centipoises on the addition of 1 per cent tragacanth gum. Essentially the same behavior is shown for karaya gum in Fig. 2. Other tests showed that the effectiveness of tragacanth and karaya gums in reducing filtration is impaired somewhat by increasing salt concentration.

Ghatti gum was very difficult to disperse in mud, but after prolonged agitation muds were prepared that had very satisfactory filtration properties. The effect of ghatti gum on filtration and viscosity of a 20 per cent suspension of Finlay clay in saturated salt solution is shown in Fig. 3. Water loss is decreased from 70 to 5 c.c. in 30 min. by the use of 0.5 per cent ghatti gum. Increasing the concentration to 1 per cent brings about a further decrease to 2.5 c.c. Viscosity of the mud does not increase continually but tends to become constant between concentrations of 0.5 and 1 per cent of gum.

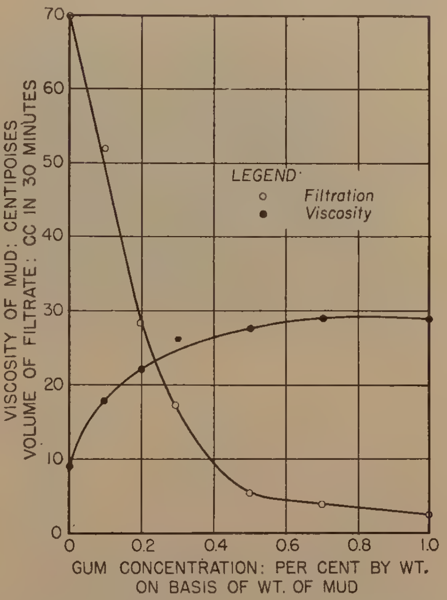
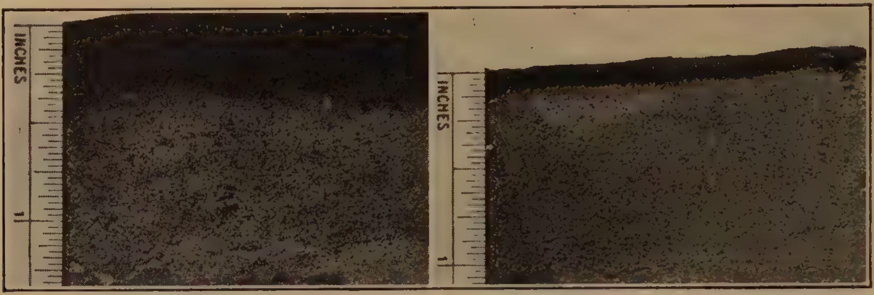


FIG. 3.—EFFECT OF GHATTI GUM ON FILTRATION AND VISCOSITY OF 20 PER CENT FINLAY CLAY IN SATURATED SALT SOLUTION.

To eliminate the possibility that the gum might be acting as sizing for the filter paper used in the wall-building tester, sand passing 100 mesh was employed as the filter medium. After the air in the pores had been displaced with salt solution, the permeability of the sand bed was found to be 2.5 darcys. Filtrations were carried out in duplicate, using 20 per cent suspensions of Shafter Lake clay in salt solution, with and without the addition of 0.5 per cent tragacanth gum. Filtration was continued for 60 min. at 100 lb. per sq. in. Filtrate volumes were 120 c.c. for the untreated sample and 20 c.c. for the sample containing gum. The thicknesses of the filter cakes formed are shown in Fig. 4. The superior wall-building qualities of the treated mud are obvious.

If gum is added to the mud, the clay concentration can be varied over fairly wide limits (10 to 20 per cent) without materially altering the filtration rate. Although the mechanism involved in reduction of filtration by gums has not been investigated in detail, it does not appear to be simply a matter of increasing the viscosity of the liquid phase, because the effect does not disappear when filtration is conducted at elevated temperatures.



a. Untreated Mud.

b. Mud Containing 0.5 Per Cent Tragacanth Gum.

FIG. 4.—INFLUENCE OF TRAGACANTH GUM ON THICKNESS OF FILTER CAKE: 20 PER CENT SHAFTER LAKE CLAY IN SALT SOLUTION FILTERED ON SAND.

Addition of Irish Moss

Irish moss, whose behavior in salt-water muds is represented in Fig. 5, is a kelp that occurs along the coasts of Ireland and New England. The viscosity and filtration effects of this material are analogous to those of the gums. However, a greater quantity is required to produce the same effect, since the active ingredient is not separated from the rest of the plant and inert material is included in the addition. A mud consisting of 20 per cent of Finlay clay in salt water of the composition given previously exhibited a water loss of 59 c.c. in 30 min. The addition of 0.5 per cent of Irish moss reduced filtration to 15 c.c. and when 1 per cent was added the value was decreased to 11 c.c. in 30 minutes.

Addition of Gelatinized Starch

Another useful method for the control of the filtration characteristics of salt-water muds was found in the addition of gelatinized starch. Starch is the principal constituent of many plants, often concentrated in the seeds, tubers, or roots. Microscopic examination reveals the starch structure as individual granules of characteristic appearance. The major portion of the starch, called amylose, is stored within a membrane designated as amylopectin. Starches from various sources have similar chemical composition but may be identified by the characteristic appearance of the granule. Most starches on hydrolysis yield as fundamental units the sugar glucose and a small quantity of acidic material derived from the cell membrane. All such glucosans, regardless of such diverse sources as seeds of rice, wheat, and corn; tubers of potato and yam; roots of cassava and arrowroot; and pith of sago palm, have been found identical in their filtration-reducing properties.

To be effective the starch must be gelatinized or pasted. The addition of dry starch or a dispersion of starch in cold water, whether untreated or the so-called soluble starch, is equivalent to the addition of a like amount of inert material. Gelatinization consists in the rupture of the amylopectin cell membrane and swelling of the cell contents. This change in structure is revealed in Fig. 6. Among the various agents that accomplish the pasting of starch, the most potent is caustic soda. The relative amounts of starch and caustic soda may be varied between rather wide limits, and the composition selected is determined by consideration of the convenience of handling the pasted mixture. A practical suspension for addition to drilling mud contains 10 per cent by weight of starch and 1 per cent of caustic soda.

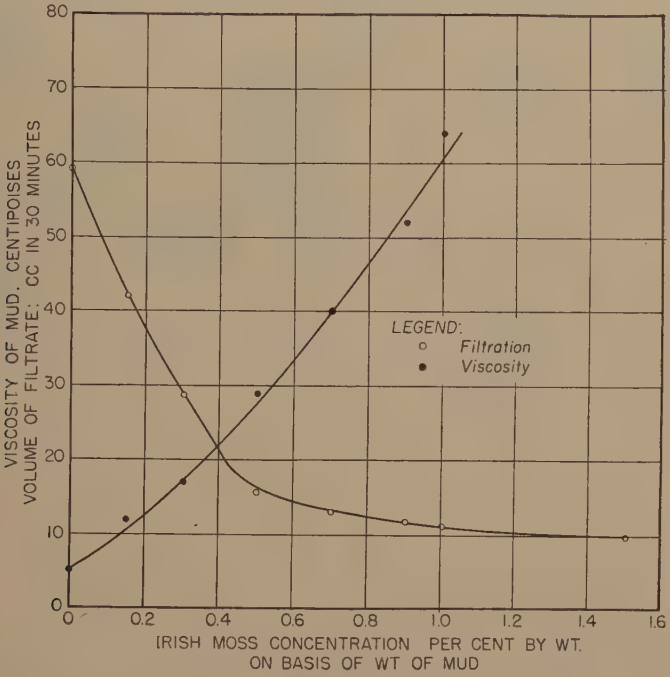


Fig. 5.—Effect of Irish moss on filtration and viscosity of 20 per cent Finlay clay in salt solution.

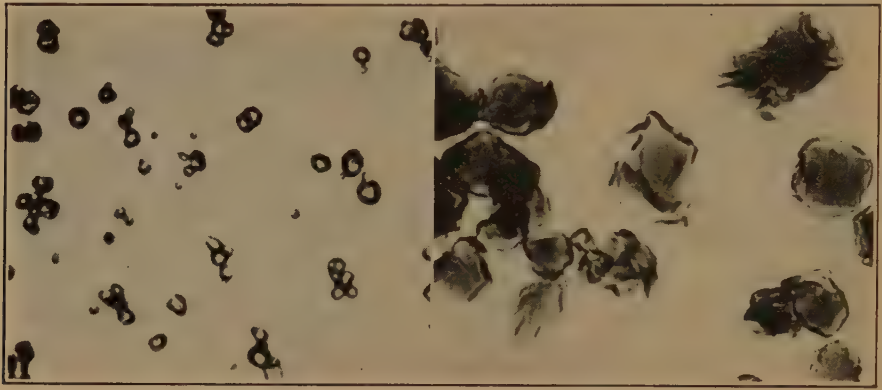
Fig. 7 presents the results of adding such a starch suspension to Finlay clay mud prepared with saturated salt solution. Starch concentration is expressed as percentage by weight of dry starch added. The addition of 1 per cent of gelatinized starch reduced the filtration of this mud from a value of 70 c.c. in 30 min. to about 5 c.c. Slightly lower values may be obtained by addition of greater quantities of starch, but water loss of about 5 c.c. may be considered a minimum for salt-water muds containing gelatinized starch. The increase in filtration observed upon the addition of small quantities of starch is characteristic for different clays, varying in magnitude from a negligible amount to an occasional quite high value. Small variations in starch concentration in the range 0.2 to 0.5 per cent produce marked changes in wall-building properties of salt-water muds.

Addition of gelatinized starch often results in erratic variations in the viscosity of salt-water muds. Usually, however, viscosity varies with starch concentration in a manner similar to that shown in Fig. 7. The viscosity increases to a maximum value, then falls off to about that of the original mud, and finally shows a slight increase. In general, salt-water muds treated with gelatinized starch show considerably lower viscosities than similar muds treated with the materials discussed earlier.

Use of Gum in Field Tests

A West Texas field that offered drilling-mud problems typical of the area was selected for a field test. In this field, about

900 ft. of salt and salt-bearing rock must be drilled before the porous limestone section from which production is obtained is reached. It was common practice, when the limestone was reached, to discard the mud used in drilling the salt section and to complete the hole with mud made from commercial clays. A bentonite slurry was spotted in the bottom of the hole before casing was run.



a. Original Granules. × 200. *b.* After Pasting. × 200.

FIG. 6.—GELATINIZATION OF CORNSTARCH.

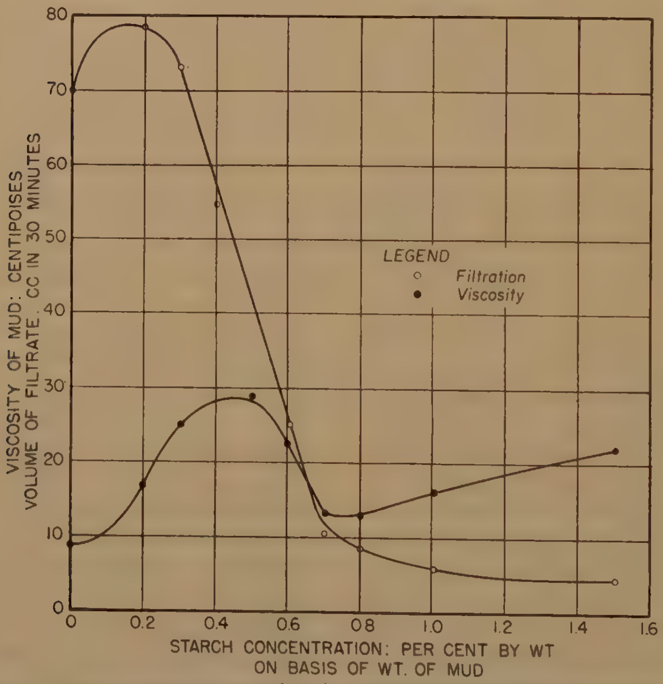


FIG. 7.—EFFECT OF GELATINIZED STARCH (10:1) ON FILTRATION AND VISCOSITY OF 20 PER CENT FINLAY CLAY IN SATURATED SALT SOLUTION.

Of the gums available, tragacanth seemed most satisfactory from the standpoint of effect on filtration and viscosity. In the first test, 1000 lb. of powdered tragacanth gum

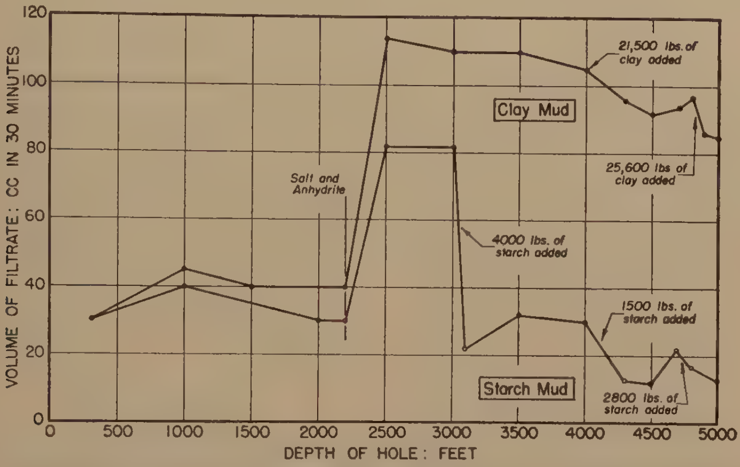


FIG. 8.—COMPARISON OF FILTRATION RATES OF MUDS CONDITIONED WITH COMMERCIAL CLAY AND WITH GELATINIZED STARCH.

was added to the mud used in drilling the salt and limestone sections. The average filtration was 70 c.c. in 30 min. On a second well, the mud was treated with 4000 lb. of tragacanth gum, and average water loss during the period of treatment was 26 c.c. in 30 min. In order to compare the treated and untreated muds, supervision was maintained simultaneously on a third well in which properties of the mud were controlled only by the addition of commercial clays. The average filtration value was 95 c.c. in 30 min. for the mud used in drilling the limestone section and 110 c.c. for that used in the salt section.

Water loss from the muds containing gum was significantly lower than from the untreated mud. The improved wall-building properties of the treated muds were shown even more definitely, although not in a way subject to numerical evaluation, by the condition of the holes. The hole drilled with clay mud alone was always tight, and it was necessary to wash out several feet of accumulated cavings and mud cake after each round trip to change bits. In contrast, no difficulty was experienced in getting back to the bottoms of the holes in which gum was used. After a twistoff in the first test well, the pipe was found to be free in the hole, whereas in other fishing jobs in this field the pipe was stuck. Bentonite slurry was not spotted on the bottom of the hole before running casing in the well on which 4000 lb. of gum was used and casing was landed and cemented without difficulty.

With the outbreak of hostilities abroad, further use of gums became impractical because of uncertainty in price and difficulty in securing delivery.

USE OF STARCH IN FIELD TESTS

The first field trial of gelatinized starch was made on a well in the same area as that of the gum tests. In preparing the pasted starch for field use, a box fitted with perforated steam coils was employed. Starch was intimately mixed with water by adding the starch through a mud-mixing hopper. Caustic soda was added, and the white, pasty mass was agitated with steam until a viscous, straw-colored suspension resulted. The final composition of the mixture was approximately 89 per cent water, 10 per cent cornstarch and 1 per cent caustic soda. The mud in the pit was stirred vigorously with the guns while the starch suspension was added.

Fig. 8 gives a comparison of the first field trial using starch and an adjacent well in which only commercial clays were used in mud control. The addition of starch was not begun until several hundred feet of salt had been penetrated. Water loss had increased from 30 to 82 c.c. in 30 min. Following the addition of 4000 lb. of starch, filtration was reduced to 22 c.c. in 30 min. Subsequent additions maintained an average water loss of 15 c.c. in 30 min. during the completion of the hole. No trouble was encountered in setting casing. The commercial clay mud showed an average water loss of 92 c.c. in 30 min. Throughout the limestone section, drilling progress was plagued by tight hole.

Table 1.—*Properties of Mud Samples from West Texas Wells*

Well No.	Density, Lb. per Gal.	Viscosity: Cp. Stormer at 600 R.p.m.	Filtration, C.C. in 30 Min.	Analysis of Filtrate, Parts per Million		
				Calcium	Chloride	Sulphate
1	11.1	10	71	1,920	133,500	5,295
2	11.6	15	69	1,830	130,000	7,200
3	11.9	27	85	1,700	154,000	4,733
4	11.2	8	220	2,775	136,500	3,550
5	10.3	5	370	2,380	74,000	4,375
6	10.5	17	330	2,420	50,000	4,320

So successful was the use of gelatinized starch in this and succeeding tests that the addition of starch to the mud prior to penetrating the limestone section became standard procedure in this area. The extension in use of starch was accompanied by a decrease in cost of drilling mud. Thus, on the test just described, mud cost was 13½¢ per foot from the surface to 5000 ft., as compared with a cost of 12¢ per foot for the clay mud in the neighboring well. The average mud cost in 50 wells subsequently drilled with mud containing pasted starch was 8.3¢ per foot from the surface, as compared with an average cost of 8.7¢ per foot for 17 wells previously drilled using commercial clay muds. Average properties and costs of these muds are summarized in Table 2. The lower cost of the starch-treated mud is due in no small measure to the increased attention given by the drilling crews to mud control in consequence of the close supervision demanded in the use of starch.

Conclusions

Laboratory tests indicated, and field use demonstrated conclusively, that filtration characteristics of salt-water muds can be improved markedly by the addition of natural gums or gelatinized starch. Additional evidence of improvement in wall-building properties was afforded by freedom from stuck drill pipe and ease of running casing to bottom in holes drilled with treated muds.

The extensive use of gums has not been undertaken because both supply and cost have been uncertain since the beginning of

Table 2.—*Comparison of Properties and Costs of Muds Conditioned with Commercial Clays and with Gelatinized Starch*

	Commercial Clay Muds	Gelatinized Starch Muds
Number of wells considered	17	50
Section drilled, feet per well	4,800	4,800
Productive section, feet per well	400	400
Filtration, cc. in 30 min.	91	15
Density, lb. per gal.	11.0	10.9
Viscosity, Marsh funnel, sec.	38	36
Starch used, lb. per well	0	4,000
Clay used, lb. per well	40,000	28,000
Cost of clay per well	$415	$225
Cost of drilling mud per foot of hole	8.7¢	8.3¢

war abroad. Starch, on the other hand, is readily available from a number of domestic sources. Pasted starch has been added to the mud used in drilling the productive section in about 80 wells in West Texas.

Although this study was directed particularly toward a solution of drilling-mud problems in West Texas fields, the results are applicable to other areas in which the mud becomes contaminated with salt. In the Gulf Coast, for example, overhanging, mushroom-type salt domes occur occasionally, and in marine operations it is frequently necessary to use sea water in making mud. In such conditions, wall-building properties of the drilling mud can be improved by the addition of gums or gelatinized starch.

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DISCUSSION

(Harold Vance presiding)

C. F. BONNET,* New York, N. Y.—The authors of this paper have shown, in a manner almost too complete for discussion, some successful mud-control methods and some of the improvements, both in mud cost and in drilling operations, that may be expected when such methods are used to maintain low "water-loss" drilling muds under difficult conditions.

They may be interested to know that observations of "water-loss" tests in our own laboratories seem to confirm their statement that the lower water loss is not entirely attributable to higher viscosity in the liquid phase of such a mud.

Especially valuable are the data given by the authors on field results. We are continually finding wide appreciation among operating men of the fact that low "water loss" in drilling mud pays dividends in better regulated and lower-cost drilling, cementing and completion of wells. Although increasing viscosities are noted in the test results cited, this should not be serious in West Texas conditions and can probably be held to reasonable limits in any field through proper balance of clay, water and starch or gum-type "water-loss" aid, together with the use of effective viscosity-reducing agents where viscosities tend to be high.

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* American Cyanamid and Chemical Corporation.

Calculation of Theoretical Productivity Factor

By H. H. Evinger* and M. Muskat*

(New York Meeting, February 1941)

A method has been developed whereby one may calculate the productivity factors of producing formations from a knowledge of the reservoir conditions. Account is taken not only of the heterogeneous character of the gas-oil flow system but also of the detailed variations with pressure of the shrinkage and viscosity of the oil, the solubility of the gas in the oil, and even the variability of the gas viscosity and the deviation of the gas from ideal behavior. Curves are shown giving the results of numerical calculations on the production rate as a function of the pressure differential for a high-pressure and a low-pressure system, three values of gas-oil ratio being treated in each case. Curves are also given showing the variation with distance from the well of the pressure, oil saturation, and permeability. The effect of connate water is briefly discussed in relation to the apparently large discrepancies between the calculated and observed productivity-factor values.

INTRODUCTION

The significance of the productivity factor as a measure of the capacity of an oil-bearing formation to produce is well recognized; for it is the composite and integrated resultant of the physical properties of both the porous medium and the fluid stream passing through it with respect to the ease with which the particular petroleum fluids present in the formation can flow through it and into producing wells.

The most direct method of determining the productivity factor of a well consists, as is well known, in the simultaneous measurement of reservoir-pressure differentials and rates of production and the expression of the data in terms of rate of flow per unit pressure drop.[1] Actual measurements carried out in this manner on producing wells have given factors that generally lie in the range of 0 to 100 bbl. per day per pound pressure drop. This wide range arises not only from variations in permeability but also from the varying sand thickness of producing formations.

One of the aims of developing a theory of the mechanics of oil production obviously is that of predicting what the productivity factor should be from a knowledge of the individual characteristics of the producing formation and the fluids produced. For homogeneous fluid systems passing through a porous medium into a producing well, it has been known for some time that the steady-state rate of liquid flow Q is given by the formula:*

$$Q = \frac{2\pi kh\Delta p}{\mu \log r_e/r_w} \qquad [1]$$

where k is the sand permeability, h its thickness, μ the liquid viscosity, Δp the pressure drop between the well and the distant parts of the reservoir, in particular that at a radius r_e, and r_w is the well radius. This gives the productivity factor:

$$f = \frac{Q}{kh\Delta p} = \frac{2\pi}{\mu \log r_e/r_w} \qquad [2]$$

which will have a numerical value for a liquid of 1 centipoise viscosity of 0.9316 or

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* Gulf Research and Development Co., Pittsburgh, Pa.

[1] From the point of view of field determinations of productivity factors, much has already been published. For instance, see references 1 to 4 at the end of the paper.

* See, for example, M. Muskat.[5]

0.8987 bbl. per day per pound drop per foot of sand per darcy, as the radius r_e is taken to be 500 or 660 ft., and the well radius is ¼ ft. The productivity factor has been expressed here in terms of unit thickness and unit permeability in order to avoid specification of their numerical values. Moreover, the sand thickness, being an extensive property, does not reflect the intensive dynamical characteristics of the flow system as long as the sand is uniform. The permeability k in principle, of course, is also an intensive property of the porous medium. It is separated out here, however, because, as will be seen later in the discussion of heterogeneous fluid systems, it will reduce essentially to a scale factor.

As already indicated, formulas 1 and 2 apply only to systems producing a homogeneous liquid. Such a condition will obtain when the oil is undersaturated with gas throughout the producing formation; that is, when the fluid pressure even at the well exceeds the saturation pressure of the gas. This is not entirely a hypothetical situation; for it has been established in recent years that in many fields the oil actually is undersaturated, an example of which is the well-known and celebrated case of the East Texas field. However, in by far the great majority of producing oil fields the oil is saturated with gas at the initial reservoir pressure, and any drop associated with movement of oil to the producing wells will lead to an evolution of gas and the development of a heterogeneous fluid system passing through the sand. In such cases the simple flow formulas given above no longer apply. The simplified form of Darcy's law for a homogeneous fluid system breaks down and must be replaced by the more complex equations characterizing the flow of heterogeneous fluid systems. During the last five years a number of investigations[6–14] have been carried out to define and develop empirically the generalizations of Darcy's law, which describe the flow of heterogeneous fluid systems. The essential result of these studies is that with each phase of the heterogeneous fluid system can be associated a permeability determined only by the local volumetric distribution within the pores of the sand; that is, the permeability concept must be generalized so as to represent a composite dynamical characteristic of the sand and each individual fluid phase. Moreover, it must be considered as variable, depending upon the specific form of the phase distribution within the sand as this varies from point to point.

These empirical relationships between the permeability to the several fluid phases and the local phase distribution within the sand or fluid saturations have been formulated into a system of the hydrodynamics for the heterogeneous flow of fluids through porous media.[15] To show the applications that might be made of this formulation, solutions were developed for the flow of a heterogeneous fluid system through a linear column of sand and also through a radial system. The latter, of course, corresponds to the practical situation of the flow of gas and oil into a well. The numerical calculations reported in that work, however, were carried out on the basis of several simplifying assumptions. Among these are: (1) the sand is unconsolidated or has the permeability saturation relationships found by Wyckoff and Botset for an unconsolidated sand; (2) the gas phase is ideal; (3) Henry's law is obeyed; (4) there is no oil shrinkage or expansion; and (5) the oil viscosity is constant.

It is the purpose of this paper to provide similar calculations for corresponding systems without the restriction of these assumptions.

The permeability saturation relationship used is that obtained by Botset[13] for a consolidated Nichols Buff sandstone. The data reported for this sand are the only ones published thus far that give both the gas and liquid permeabilities for a consolidated sand. They were used therefore throughout the present calculations, even though it is realized that they may not apply in detail to all other types of consolidated sand.

In the calculations made on the low-pressure reservoirs, the gas phase was still taken as ideal, since no data were available regarding the deviation factors for the gas phase. For the higher-pressure systems, however, deviation factors were derived and used in the calculations, as will be explained later.

In all the computations to be reported, the solubility of the gas in the oil was taken to be that determined empirically and, of course, did not follow Henry's law with any precision. Likewise, shrinkage or expansion factors were applied to the liquid phase in accordance with direct empirical observations.

With respect to the oil viscosity, the effect of the gas in solution was taken into account in all the computations, as will be explained in detail in the discussion.

ANALYTICAL PROCEDURE

The general hydrodynamic formulation of the flow of heterogeneous fluids through porous media can be expressed by the equations 3*a* and 3*b*

$$\nabla \cdot \left(\frac{k_l}{\beta \mu_l} \nabla p \right) = f \frac{\partial}{\partial t} (\rho / \beta) \qquad [3a]$$

$$\nabla \cdot \left(\frac{S}{\beta} \frac{k_l}{\mu_l} \nabla p + \frac{\gamma k_g}{\mu_g} \nabla p \right) = f \frac{\partial}{\partial t} \left\{ \frac{S \rho}{\beta} + \gamma (1 - \rho) \right\} \qquad [3b]$$

where k_l and k_g are the empirically determined permeabilities to the liquid and gas phases, μ_l and μ_g are the viscosities of the liquid and gas phases, p is the fluid pressure, S is the solubility of the gas in the liquid expressed as total gas dissolved per unit volume of residual liquid, β is the expansion factor of the oil in terms of the residual oil volume and corresponds to one plus the factor generally termed "shrinkage factor," γ is the density of the gas phase, ρ is the local liquid saturation, f is the sand porosity, and t is the time variable.

These equations are identical with those previously given[15] except for the inclusion of the expansion factor β. Only two equations have been written here, on the assumption that there will be only two mobile phases. Of course, if there should be a third mobile phase, such as the connate water, a third equation similar in structure to 3*a* must be added. In fact, its exact form will be identical with that of 3*a*, with the term β omitted and the variables k_l, μ_l and ρ referring to this third phase, except as one might take into account still further refinements such as the solubility of the gas in the third phase.

Under steady-state conditions, the right sides of Eqs. 3*a* and 3*b* must be set equal to zero. Strictly speaking, there will be no such thing as a steady state in a heterogeneous fluid system producing gas and oil, except as it is subject to a complete water drive—and even then the external boundary of the system will not be constant. For practical purposes, however, the actual transient history of oil and gas reservoirs may be represented by a slowly varying succession of steady states. It is such equivalent steady-state conditions to which the determination of a productivity factor is generally referred, and which will form the basis for the present calculations. This question of the assumption of steady-state conditions enters specifically in the numerical calculations and also in the choice of the permeability saturation relationship expressed by $k = k(\rho)$; for in Botset's experiments[13] it was shown that steady-state conditions of flow could not be maintained with liquid saturations above the equilibrium value. In practical field operations, however, the drop of the oil saturation everywhere at least to the equilibrium value would imply an appreciable total production from the reservoir, and hence that the field has already passed through a large part of its productive history. To obtain results corresponding to the early part of the production history of a reservoir, therefore, we have assumed that the flow systems are in substantially steady states even at liquid saturations higher than the equilibrium value. Moreover, in accordance with this assumption, we have arbitrarily extrapolated the gas-permeability curve in a parabolic manner so as to fall to zero values only at 100 per cent saturation rather than the equilibrium saturation, as it would if the systems were operating under strictly steady-state conditions throughout. In this respect also the calculations presented here for the low gas-oil ratios differ from those previously published.[15]

Applying Eqs. 3*a* and 3*b* for the steady-state conditions directly to radial flow systems, we may write down at once their first integrals as:

$$Q_l = \frac{2\pi r h}{\beta}\frac{k_l}{\mu_l}\frac{dp}{dr} \tag*{[4a]}$$

$$Q_g = 2\pi r h\left(\frac{S}{\beta}\frac{k_l}{\mu_l} + \frac{\gamma k_g}{\mu_g}\right)\frac{dp}{dr} \tag*{[4b]}$$

where h is the sand thickness, Q_l is the volume rate of production of residual oil, and Q_g is the rate of gas flow expressed in mass or volume units under standard conditions.

A simple division gives:

$$R = \frac{Q_g}{Q_l} = S + \alpha(p)\Psi(\rho) \tag*{[5]}$$

where

$$\alpha(p) = \gamma\beta\mu_l/\mu_g; \qquad \Psi(\rho) = k_g/k_l.$$

R represents the gas-oil ratio, $\alpha(p)$ is a composite factor varying only with the pressure (since the systems are assumed to be isothermal throughout this work), and $\Psi(\rho)$ depends only upon the liquid saturation. Thus $\alpha(p)$ depends exclusively on the properties of the fluid system whereas $\Psi(\rho)$ is determined essentially by the nature of the sand. At the same time the integral of Eq. 4*a* can be formally expressed as:

$$\frac{Q_l}{2\pi h k_o}\log\frac{r_e}{r} = \int_p^{p_e}\frac{k_l/k_o}{\mu\beta}\,dp \tag*{[6]}$$

where p_e is the effective reservoir pressure—that is, the fluid pressure at the radial distance r_e—and k_o is the homogeneous fluid permeability. The evaluation of the integrals and manner of the calculations may then be carried out as follows:

Choosing the value for the gas-oil ratio, the relationship between ρ and p can be computed by means of Eq. 5. Applying this relationship to the integrand of Eq. 6, the indefinite integral can be evaluated, thus giving the pressure distribution in the system. The numerical value of the rate of oil production is obtained from the evaluation of the integral for the pressure p corresponding to the well pressure. In fact, by varying the well pressure, the relationship between the production rate and pressure differential is obtained. The latter, of course, gives directly the productivity factor. Going back to Eq. 5, the saturation and permeability distributions can be obtained from the pressure distribution. As can be seen at once from the nature of this procedure, the absolute values of the rates of oil production and of the productivity factors depend upon the gas-oil ratio. Moreover, in view of the variable character of the integrand of Eq. 6, it may be anticipated directly that the productivity factor will not be a constant even for a fixed gas-oil ratio, but will depend also upon both the reservoir pressure and the pressure differential.

NUMERICAL APPLICATIONS

Low-pressure Reservoir

For this system the gas-solubility, oil-expansion factor, and oil-viscosity variation used in the calculations were those given in the curves of Fig. 1. The solubility and expansion factors were those actually measured for an oil from an Illinois field. Its gravity was 39.5°A.P.I. at 60°F. The viscosity of this particular oil was not determined directly. Rather, the values shown in Fig. 1 are those corresponding to curve 2 of the viscosity-pressure curve published by Hocott and Buckley[16] which happen to have approximately the same terminal solubility and expansion factors as those given by the directly measured solubility and expansion curves.* As previously indicated, gas-deviation factors were not available for the gas phase of this particular system and the gas phase therefore was assumed to be ideal. Its viscosity was taken to be 0.01 centipoise. The permeability vs. saturation function $\Psi(\rho)$ that was used throughout all the calculations was based on the data of Botset[15] for the Nichols Buff sandstone, with the modification previously indicated. The individual permeability curves for the liquid and gas phases are shown in Fig. 2, for the ranges of ρ entering in the calculations.

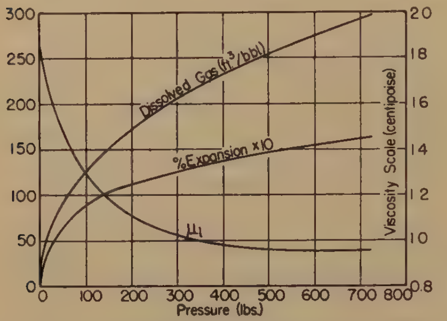

FIG. 1.—SOLUBILITY, EXPANSION FACTORS, AND OIL VISCOSITY UNDER RESERVOIR CONDITIONS FOR THE LOW-PRESSURE RESERVOIR SYSTEM AS A FUNCTION OF THE PRESSURE (GAUGE). EXPANSION FACTORS ARE EQUIVALENT TO $\beta - 1$.

The results of the calculation of flow rate vs. pressure differential, as obtained in the manner outlined above, are shown in Fig. 3 for a reservoir pressure p_e of 725 lb. gauge. The external radius r_e was chosen to be 500 ft. and the well radius r_w as ¼ ft. The calculations were carried out for gas-oil ratios of 297, of 500 and 2000 cu. ft. per bbl., the figure 297 representing the case in which the fluid at r_e is entirely a saturated liquid. The ordinates represent the rate of flow in barrels per day per foot of sand and for a homogeneous fluid permeability of 1 darcy.

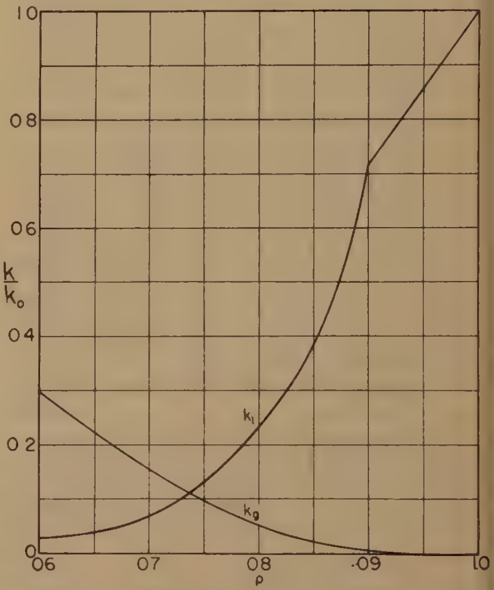

FIG. 2.—PERMEABILITY-SATURATION RELATIONSHIP FOR RESERVOIR SAND IN THE HIGH-SATURATION REGION.

ρ = liquid saturation expressed as fraction of pore space; k_o = homogeneous fluid permeability; k_l and k_g are permeabilities to liquid and gas phases.

The slopes of these curves should give the value of the productivity factor, as defined by Eq. 2. The dashed curves correspond to a system where the oil viscosity remains fixed at its surface value of 1.87 centipoises, whereas for the solid curves the variation of the viscosity with pressure, according to the viscosity curve of Fig. 2, was taken into account. If the problem under consideration referred to a homogeneous fluid system of 1.87 centipoises viscosity, with no expansion due to dissolved gases, the curves of Fig. 3 would all fall on the straight line through the origin of slope 0.498, as given by Eqs. 1 and 2. In contrast to this, the actual curves not only diverge among themselves but they are all convex upward, indicating a decreasing effective productivity factor with increasing pressure differential. This means that even for a fixed gas-oil ratio and fixed behavior of the fluids produced, the productivity factor is not a constant, but varies with the rate of production, as is actually observed in practice. The reason for this variation lies, of course, in the heterogeneous character of the flow. In particular, it is a consequence of the fact that as the pressure differential increases the greater evolution of gas from the oil near the well requires an increased free gas space or lower oil saturation. The decreasing permeability for the oil as the saturation goes down leads to a greater over-all sand resistance and hence lower productivity factor.

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* The authors are indebted to Mr. Rex Woods of the Gulf Oil Corporation for the data on solubility and expansion factor, and to S. E. Buckley and C. R. Hocott for the viscosity and related information for the oil they used in their experiments.

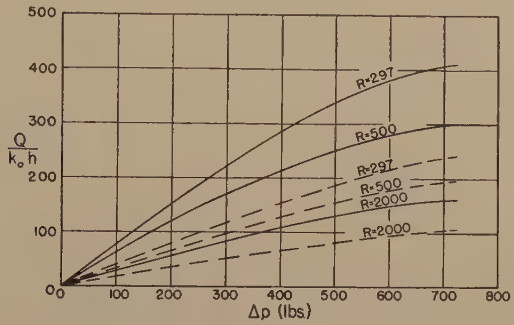

FIG. 3.—PRODUCTION RATE VS. PRESSURE DIFFERENTIAL FOR RESERVOIR PRESSURE OF 725-LB. GAUGE.

R = gas-oil ratio, cu. ft. per bbl. Q/k_oh = bbl. per day per ft. sand per darcy. For dashed curves liquid viscosity is taken as fixed at 1.87 centipoise. For solid curves the viscosity variation is taken into account.

The dashed curves of Fig. 3 are of interest in showing directly the effect of the variable liquid saturation and fluid permeabilities through the sand, since the oil viscosity is kept fixed at its surface value. The solid curves, on the other hand, include the composite effect of variable permeability and variable viscosity, and show that the decrease in viscosity due to the dissolved gases may raise the effective productivity factor so as to be materially higher than if the viscosity were the same in the sand as it is at the surface. The divergence of the curves for the different gas-oil ratios shows the importance of taking into account the heterogeneous character of the flow system; for as the gas-oil ratio increases the increased free gas space required to carry the excess gas again forces a contraction in the oil saturation and hence lower liquid permeabilities and over-all productivity factors. To obtain a quantitative measure of these various effects involved in the present discussion, we may compare the limiting slopes at zero pressure differential of the curves of Fig. 3 with the slope of the straight line that would correspond to the homogeneous fluid system for an oil of 1.87 centipoises; namely, 0.498. Thus, considering this productivity factor as unity, the relative productivity factors corresponding to the various curves of Fig. 3 would be for the dashed curves—the oil viscosity kept fixed—0.86, 0.67, and 0.38 for gas-oil ratios of 297, of 500, and 2000 cu. ft. per bbl. For the solid curves the relative factors would be 1.71, 1.25, and 0.61 for gas-oil ratios of 297, of 500, and 2000 cu. ft. per bbl. From these numbers we see at once that except for the gas-oil ratio of 2000 the effect of the dissolved gas in reducing the oil viscosity more than counterbalances the drop in liquid saturation and oil permeability due to the heterogeneous character of the flow. The importance of taking into account the variation of the oil viscosity with the dissolved gas will be quite obvious, therefore, especially in view of the fact that in many cases the total range of variation of viscosity with the solution pressure may be considerably larger than that shown in Fig. 1.

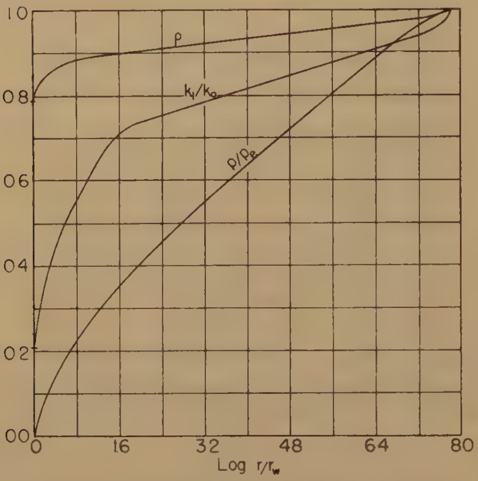

FIG. 4.—SATURATION, RELATIVE LIQUID PERMEABILITY, AND PRESSURE DISTRIBUTIONS IN RESERVOIR SAND PRODUCING AT GAS-OIL RATIO OF 297 CU. FT. PER BBL. WITH RESERVOIR PRESSURE OF 725-LB. GAUGE.

r_w = well radius; r = radial distance from well center; ρ = saturation; k_l/k_o = relative liquid permeability; p/p_e = pressure at radius r/reservoir pressure.

The details of the saturation, permeability, and pressure distributions for gas-oil ratios of 297 and 2000 cu. ft. per bbl. are shown in Figs. 4 and 5. Since the smaller of these gas-oil ratios corresponds to the solution ratio at the reservoir pressure of 725 lb., both the saturation and permeability curves begin at the unit ordinate at the reservoir radius r_e. The rather sharp initial drop in the saturation and permeability curves results from the vanishingly slow rise in the $\Psi(\rho)$ curve as the saturation is decreased from unity. As was observed in the case of the previously published calculations,[15] the major drop in the saturation and permeability curves takes place right near the well surface, this effect also obviously explaining the curvature of the pressure-distribution curve. The break in the permeability curve at the abscissa value of about 1.5 arises from the break in slope of the basic permeability vs. saturation curve occurring at a saturation of 0.9, as may be verified from Fig. 2.

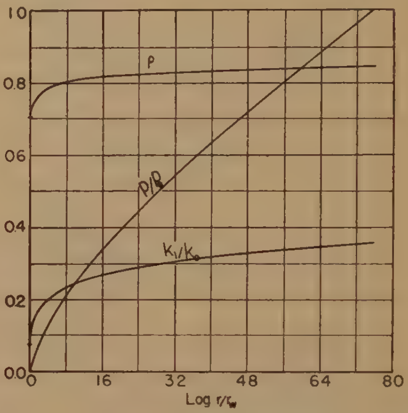

FIG. 5.—SATURATION, RELATIVE LIQUID PERMEABILITY, AND PRESSURE DISTRIBUTION IN RESERVOIR SAND PRODUCING AT GAS-OIL RATIO OF 2000 CU. FT. PER BBL. WITH RESERVOIR PRESSURE OF 725-LB. GAUGE.

r_w = well radius; r = radial distance from well center; ρ = saturation; k_l/k_o = relative liquid permeability, p/p_e = pressure at radius r/reservoir pressure.

In the case of the gas-oil ratio of 2000 cu. ft. per bbl., the limiting values of the permeability and saturation are no longer unity, since even at the reservoir boundary the sand must carry an excess of gas beyond that which is in solution. Here the liquid saturations are less than 0.9 throughout the sand, thus explaining the absence of the previously mentioned break in the permeability curve. The concentration of the drop in saturation and permeability about the well bore is present here too, and in the same way as before explains the deviation from linearity of the pressure distribution curve. The saturation, permeability, and pressure distribution for the gas-oil ratio of 500 cu. ft. per bbl. obviously will be intermediate between those shown in Figs. 3 and 4.

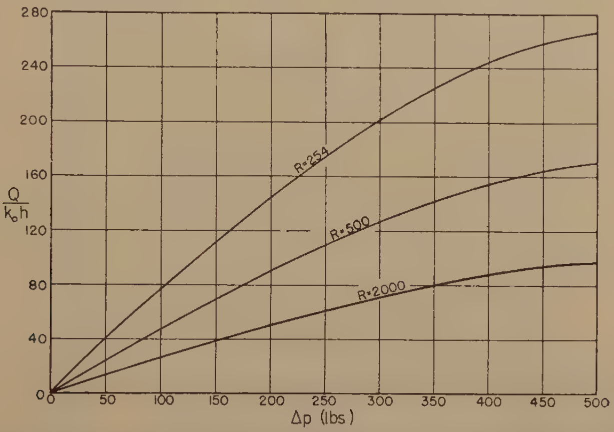

Fig. 6.—Production rate vs. pressure differential for reservoir pressure of 500-lb. gauge.

R = gas-oil ratio, cu. ft. per bbl.; Q/k_oh = bbl. per day per ft. sand per darcy.

If the reservoir pressure should be 500-lb. gauge, the relationship between the flow rate and pressure differential will be as shown in Fig. 6. For this case the gas-oil ratio of 254 corresponds to the solution ratio at the reservoir pressure. The general features of the curves of Fig. 6 are similar to those of Fig. 3 and need little further discussion. It may be observed, however, that again the relative productivity factors corresponding to the slopes of these curves near the origin as compared to the slope of 0.498, which would obtain in the case of a homogeneous fluid system, are: 1.608, 0.998, and 0.534 for the gas-oil ratios of 254, 500, and 2000 cu. ft. per bbl. Recalling the values previously found for a reservoir pressure of 725 lb., we see that the productivity factor will decrease with decreasing reservoir pressure. This effect, however, is to be expected both as a result of the average higher viscosities in the low-reservoir-pressure system, and the fact that the average liquid saturation and liquid permeability must be lower in order that the system may have the same total gas-oil ratio with the lower solution pressures.

High-pressure Reservoir

The calculations to be reported in this section are based upon data of Sage and Lacey obtained in the study of the oil and gas produced from the Fifth Calendar zone of the Dominguez field.[17] The reservoir pressure to be considered here—namely, 2500 lb.—is certainly not high when compared with those encountered in the drilling of recent years. However, it is approximately the highest for which complete data have been published, including not only the solubility and expansion factors for the gas and oil, but also the viscosity of the gas-saturated oil. These basic data are plotted in Fig. 7 for formation temperatures of 190°F. and gauge pressures to 2500 lb. Here again the solubility and expansion factors are expressed in terms of residual oil. The liquid viscosities were obtained by interpolation from the data of Sage and Lacey. The gas viscosity was here taken to be variable according to the curve shown in

Fig. 7. This curve was obtained by interpolation from the viscosity-pressure curve determined by Sage and Lacey[18] for a lean natural gas. The high mol percentage of methane (87.78 per cent) and the low gasoline content of the gas used in the study of the Dominguez field indicated that the gas was more like the lean gas than the rich gas used in their gas-viscosity investigation.

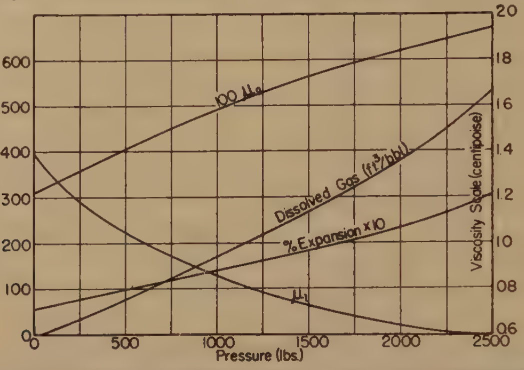

FIG. 7.—SOLUBILITY, EXPANSION FACTORS, AND OIL AND GAS VISCOSITIES UNDER RESERVOIR CONDITIONS FOR HIGH-PRESSURE RESERVOIR SYSTEM AS FUNCTION OF PRESSURE (GAUGE). EXPANSION FACTORS ARE EQUIVALENT TO $\beta - 1$.

Fig. 7 shows that the solubility and expansion curves are here everywhere concave upward in contrast to those of Fig. 1, which are convex upward throughout the range plotted there. The latter behavior, of course, is that commonly observed in normal gas-crude oil systems. The different type of variation shown in Fig. 7 is explained by Sage and Lacey as being due to the fact that the systems are approaching a critical state. Presumably this critical state would correspond more to the type obtaining with pure substances, since the accelerated rise in the solubility and expansion curves seems to indicate an increased condensation of liquid out of the gas phase. In any case this behavior does not imply that the system is in the retrograde region and is approaching the dew point; for under those circumstances the expansion factor would decrease with increasing pressure and the gas dissolved in the liquid phase would drop off in a similar manner.

Densities of the gas phase were calculated by subtracting the bubble-point formation volumes at various pressures from the composite two-phase formation volumes. On subtraction of the bubble-point gas solubility from the total gas-oil ratio, the surface volume of gas in the gas phase was obtained. By dividing this surface volume by the actual formation volume of the gas phase, the effective density was obtained. These are plotted in Fig. 8.

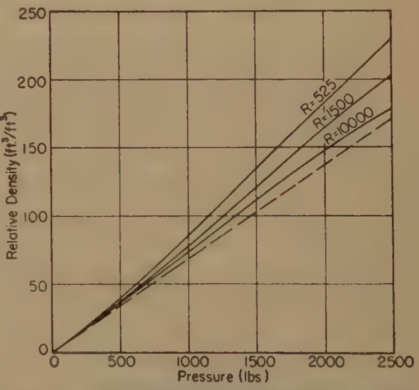

FIG. 8.—RELATIVE GAS DENSITIES AS FUNCTION OF PRESSURE (GAUGE) FOR VARIOUS GAS-OIL RATIOS.

Dashed line represents ideal gas behavior.

The method of calculation just outlined is subject to error because of the assumption that the formation volume of the liquid in the two-phase system is the same as the bubble-point formation volume.

However, because of lack of more directly determined data, the results obtained by the procedure indicated were taken to be sufficiently accurate for the practical purposes of the present problem. The gas densities are different for the different gas-oil ratios (Fig. 8). This, however, is to be expected because of the differences in gas composition of the gas phase in the various gas-oil ratio combinations. From the same consideration one can see why the higher gas-oil ratio systems would involve greater degrees of dilution of the gas phase with the dry gas and hence result in lower gas phase densities. The ideal gas-law behavior for the gas phase is indicated by the dashed line of Fig. 8. If the deviations of the calculated curves from the straight line be interpreted in terms of the conventional *pv* vs. pressure plot it will be noted that for the gas-oil ratios of 525 cu. ft. per bbl. the curve throughout the whole range of pressure is on the downward segment. For the gas-oil ratio of 1500 cu. ft. per bbl., the *pv* plot would already show an approach to a minimum, and for the highest gas-oil ratio curve the minimum would be reached at about 2000 lb. and the curve would have traversed an appreciable part of the rising segment by the time the pressure of 2500 lb. was reached.

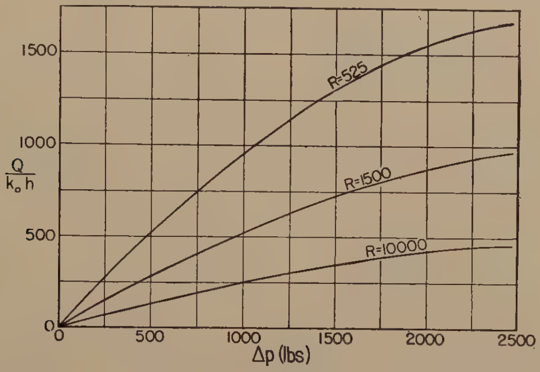

FIG. 9.—PRODUCTION RATE VS. PRESSURE DIFFERENTIAL FOR RESERVOIR PRESSURE OF 2500-LB. GAUGE.
R = gas-oil ratio, cu. ft. per bbl.; $Q/k_o h$ = bbl. per day per ft. sand per darcy.

The productivity calculations were carried out as in the previous case. The results for a reservoir pressure of 2500 lb. gauge are shown in Fig. 9. The general features of these curves are the same as those previously found for the low-pressure reservoir system, and again show the dependence of the productivity factor both upon the gas-oil ratio and the absolute value of the pressure differential. To get a measure of the quantitative effect of these factors, we may note that since the surface viscosity of the oil is in the present case 1.38 centipoises the productivity factor for a homogeneous liquid of this viscosity and with no expansion would be 0.675 bbl. per day per lb. per darcy. Considering this homogeneous value once more as unity, the limiting values of the productivity factor for the heterogeneous system and variable viscosity will be, for vanishing pressure differentials, 1.85, 1.12, and 0.41 for gas-oil ratios of 525, 1500, and 10,000 cu. ft. per bbl., respectively.* Thus we see that for the low gas-oil ratios the effect of the variability in viscosity more than counterbalances that due to the expansion factor and the drop in permeability, so as to give a relatively high productivity factor, whereas for the gas-oil ratio of 10,000 cu. ft. per bbl. the drop in fluid saturation and permeability is evidently the predominating factor. The fluid saturation, permeability, and pressure-distribution curves for the two extreme gas-oil ratios (525 and 10,000 cu. ft. per bbl.) are shown in Figs. 10 and 11, respectively. Since the gas-oil ratio of 525 cu. ft. per bbl. is the saturation ratio at the reservoir pressure of 2500 lb., the saturation and relative permeability at the effective reservoir radii are unity in this case. As a whole the curves of Figs. 10 and 11 are similar to those previously found for the low-pressure reservoir, and need no further discussion.

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* Because of the steep character of the saturation and permeability curves at the reservoir radius for the saturation gas-oil ratios (Figs. 4 and 10) the Q vs. Δp curves for these cases will rise very sharply at vanishing Δp. As this detailed variation cannot be shown on the graphs, the apparent productivity factors for these cases as read off the curves will be somewhat lower than the true factors.

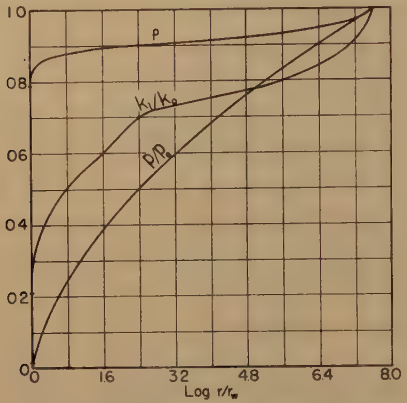

Fig. 10.—Saturation, relative liquid permeability, and pressure distributions in reservoir sand producing at gas-oil ratio of 525 cu. ft. per bbl. with reservoir pressure of 2500-lb. gauge.

r_w = well radius; r = radial distance from well center; ρ = saturation; k_l/k_o = relative liquid permeability; p/p_e = pressure at radius r/reservoir pressure.

Conclusions

As a whole, the results discussed in the preceding sections give a rather discouraging picture regarding the possibility of calculating productivity factors theoretically from simple homogeneous fluid considerations. They show definitely that in a heterogeneous fluid system the productivity factor will depend not only upon the detailed characteristics of the fluid and sand, but also upon the gross and over-all parameters such as the gas-oil ratio, pressure differential, and absolute reservoir pressure. In fact, because of the curvature of the plots of flow rate vs. pressure differential, there is in a strict sense no productivity factor at all that can be assigned to a gas and oil-producing system with any range of validity. Perhaps the only practical definition therefore would consist in restricting the productivity factor to the limiting slope of the curve of flow rate vs. pressure differential as the pressure differential is made vanishingly small. These are the productivity factors used in the comparisons made above. But even they, as has already been indicated, depend upon both the gas-oil ratio and absolute reservoir pressure as well as upon the fluid and sand properties.

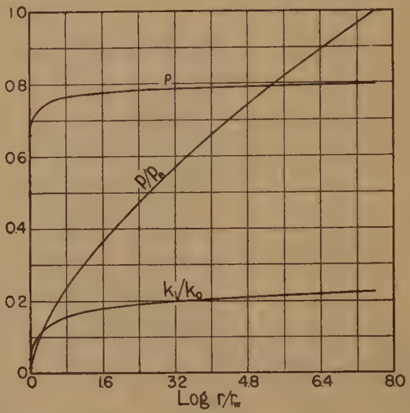

Fig. 11.—Saturation, relative liquid permeability, and pressure distributions in reservoir sand producing at gas-oil ratio of 10,000 cu. ft. per bbl. with reservoir pressure of 2500-lb. gauge.

r_w = well radius; r = radial distance from well center; ρ = saturation; k_lk_o = relative liquid permeability; p/p_e = pressure at radius r/reservoir pressure.

Unfortunately, there is no simple correlation evident between the various productivity factors found in the above calculations and the variations in the parameters defining the individual cases. About all that can be definitely stated is that in the limit of vanishing pressure differential the productivity factor can be expressed by a generalization of Eq. 2 in the form:

$$f = \frac{Q}{k_0 h \Delta p} = \frac{2\pi (k/k_o)_e}{\mu_e \log r_e/r_w} \qquad [7]$$

where again k_o is the homogeneous fluid permeability and the quantities $(k/k_o)_e$ and μ_e represent the effective values of the actual relative liquid permeability and viscosity within the flow system.

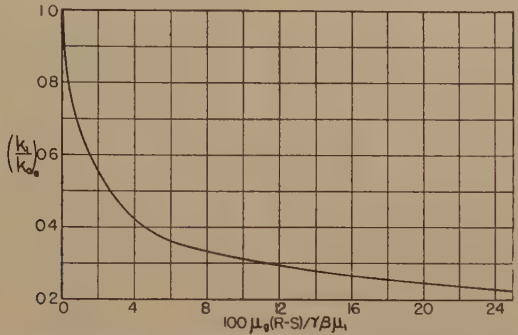

FIG. 12.—PLOT OF EFFECTIVE LIQUID PERMEABILITY VS. PHYSICAL PARAMETERS OF FLOW SYSTEM.
k_o = homogeneous fluid permeability; μ_g, μ_1, are viscosities of gas and liquid phases; γ = gas-phase density; and β = expansion factor, all at reservoir pressure. S = saturation solubility and R = gas-oil ratio.

On the assumption that the total pressure drop over the sand is vanishingly small, one may take for μ_e the liquid viscosity at the reservoir pressure and for the effective relative permeability that obtaining at the reservoir radius r_e. Under these conditions one may relate the effective value of the relative liquid permeability to the other physical parameters of the system; namely, the gas viscosity, the gas-phase density, the oil-expansion factor, the reservoir-pressure solubility, and the over-all gas-oil ratio. This relationship, which is difficult to express in simple mathematical form, is shown in Fig. 12, where the relative permeability is plotted against the composite function of the above-mentioned variables. Thus if one knows the numerical values of the variables, the abscissa of Fig. 12 can be computed, and the effective value of the relative permeability can be read from the curve. Putting this value into Eq. 7, the limiting productivity factor for vanishing pressure differentials will be obtained. In this way can be avoided at least the necessity of going through the detailed calculations and integrations required for establishing the complete curves of flow rate vs. pressure differential and the saturation-permeability and pressure-distribution curves.

It will be noted from Fig. 12 that up to abscissa values of 25, which includes the numerical cases previously considered, the maximum reduction in productivity factor due to the heterogeneous character of the flow will correspond to a ratio of 4.5 between the homogeneous and heterogeneous factors. This ratio seems to be far too small to account for the empirical curve of Pyle and Sherborne[19] relating the productivity index with the average sand permeability. According to this latter curve (Fig. 21[19]) the observed productivity factor might be even less than 1/60 of that calculated from the average sand permeability on the basis of homogeneous fluid. As has already been indicated, no account has been taken in the calculations or in Fig. 12 of the possible effect of connate water on the productivity factor. To see whether the discrepancy between Fig. 12 and the implications of Fig. 21 of Pyle and Sherborne might be accounted for by the effect of connate water, additional calculations were carried out for the limiting productivity factors for systems in which the connate-water saturation was either 30 or 40 per cent. The permeability-saturation data used for these calculations were obtained from the work of Leverett and Lewis[14] for an unconsolidated sand. The results are shown in Table 1. The values in column 2 corresponding to a water-free sand do not agree exactly with those given previously and plotted in Fig. 12, because the permeability-saturation relationship of unconsolidated sand was used here, as well as for the sands containing water, so as to obtain a more direct indication of the effect of the connate water. It will be noted that the connate water may have a very material effect in cutting down the observed productivity factor, although it seems that not all of the discrepancy between the theoretical predictions and the observations of Pyle and Sherborne can be thereby explained. In any case, it is clear that in order to make even a semiquantitative theoretical prediction of the productivity factor one should take into account the connate-water saturation as well as all the other various factors already considered.

TABLE 1.—*Calculations for Systems Containing Connate Water*

Factors[a]	R, Cu. Ft. per Bbl.	$(k_l/k_o)_e$		
		$\rho_w = 0$	$\rho_w = 0.3$	$\rho_w = 0.4$
$p_e = 725$	297	1.000	0.310	0.150
$\mu_e = 0.94$	500	0.815	0.280	0.115
$\beta_e = 1.163$	2,000	0.487	0.207	0.073
$p_e = 500$	254	1.000	0.310	0.150
$\mu_e = 0.96$	500	0.725	0.268	0.109
$\beta_e = 1.147$	2,000	0.440	0.183	0.061
$p_e = 2500$	525	1.000	0.310	0.150
$\mu_e = 0.57$	1,500	0.620	0.250	0.100
$\beta_e = 1.305$	10,000	0.308	0.097	0.038

[a] ρ_w = water saturation; p_e, μ_e, β_e = pressure, oil viscosity, and expansion factor at the reservoir radius; $(k_1/k_o)_e$ = effective over-all permeability ratio.

A final limitation to the applicability of these results arises from the assumption of the steady-state character of the flow system, already discussed. It must be admitted that herein lies a real uncertainty in the application of any formulas or method for the calculation of productivity factors. However, it is felt that when a well has been producing at a fixed rate for an extended period of time the steady-state approximation should be reasonably accurate. In any case, it would be desirable to obtain definite evidence on this point from direct well measurements.

ACKNOWLEDGMENTS

The authors are indebted to Dr. Paul D. Foote, Executive Vice-President of the Gulf Research and Development Co., for permission to publish this paper.

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DISCUSSION

(*C. A. Warner presiding*)

E. G. Trostel,* Alhambra, Calif.—The authors say that theoretical calculations show that the productivity factor should vary over wide limits with changes in pressure differential and gas-oil ratio. It has been my experience that the productivity factor, or productivity index, as actually measured will usually remain sensibly constant over a wide range of variance in pressure differential and often gas-oil ratio. This fact has been reported in the literature by several investigators. I should like to ask how the authors reconcile the theoretical considerations with such experimental field data.

M. Muskat (author's reply).—Mr. Trostel's comments are well taken. For the theoretical calculations of the paper do show that the productivity factors of producing sections may vary over wide limits, depending upon the gas-oil ratio, and possibly by a factor of two with variations in the pressure differential. These calculations, however, refer to steady-state conditions and are not directly applicable to the interpretation of short-period transient fluctuations. Thus they imply that there should be a gradual decrease in the productivity factor in gas-drive fields as the gas-oil ratio increases during the course of the production history, but do not apply to the prediction of the results of production tests under varying conditions over periods of the order of a few days. Mr. Trostel's remark that his experience shows a constancy of the productivity factor is of value in suggesting the need for further detailed study of individual well performance. However, this would be greatly assisted by the presentation of the quantitative field data and conditions of tests upon which his conclusions were based. It is only when such detailed data are available that interpretations can be made of individual well behavior.

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* Union Oil Co.

Density of Natural Gases

By Marshall B. Standing* and Donald L. Katz,* Member A.I.M.E.

(New York Meeting, February 1941)

Density data are reported on 16 saturated hydrocarbon vapors at pressures ranging from 1000 to 8220 lb. per sq. in. and at temperatures ranging from 35° to 250°F. These data have been used to extend the compressibility-factor chart for natural gases up to 10,000 lb. per sq. in. The relatively large quantity of high-boiling constituents present in high-pressure vapors in equilibrium with crude oils makes it necessary to include in the analysis of the gas the molecular weight, density, and possibly boiling range of the heptanes and heavier fraction. Relationships have been presented by which the density of gases may be obtained directly from the temperature, pressure, and gas gravity provided the gases have a common source or are similar in composition.

Introduction

The densities of natural gases are necessary in many engineering computations in petroleum production and utilization. Gas reserves, changes in reservoir pressure, gradients in gas wells, metering of gases, pipeline flow, and compression of gases are typical problems requiring the density of the gas. A decade ago, engineering computations used ideal gas laws with deviations up to 500 lb. per sq. in.[4] Recent discoveries of pools having pressures up to 7500 lb. per sq. in., and installation of pressure-maintenance and recycling plants, have increased the need for data on gas density at high pressures.

Methods of Computation

The accepted method of computing the density or specific volume of natural gases is the use of the ideal gas law corrected by a compressibility factor. The method proposed by Kay[7] of correlating compressibility factors for gaseous mixtures on pseudocritical properties[5] appears to be satisfactory for natural gases.[2] The methane-compressibility factor has been shown to deviate systematically from the behavior of natural gases[2] and a chart giving these corrected factors is available.

A method of computing specific volume of gaseous mixtures from partial molal volumes has been reported by Sage and Lacey.[8] Complete data for the computation are not yet available for all hydrocarbon gases.

Most of the reported data on gas densities have been in the single-phase region removed from the dew point or saturation condition. Since most gases in the reservoir or while on contact with liquid during flow are saturated, the determination of densities under conditions of saturation is particularly important. Although there is no reason to believe that the saturated gases differ in behavior from those considerably removed from their dew points, the usual experimental determinations find difficulty on approaching the dew-point conditions.

This paper reports the density of 16 saturated gases in equilibrium with crude oils. The relationships developed to compute the density of gases to high pressure[1] have been modified and enlarged. A simplified method of obtaining gas density is presented in the form of charts, which apply for specific groups of gases.

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* University of Michigan, Ann Arbor, Mich.

[4] References are at the end of the paper.

DATA OBTAINED

In the process of obtaining equilibrium data on mixtures of natural gas and crude oils, the density and analysis of the saturated vapor phases were obtained. These data were in the range of 35° to 250°F. and 1000 to 8220 lb. per sq. inch.

The vapors in equilibrium with crude oil were transferred, by mercury displacement, at constant temperature and pressure from the equilibrium cell into pycnometers of 25-ml. capacity. The contents of the pycnometer were discharged into a low-temperature fractionating column, to obtain the analysis of the gas. In all cases the pycnometer was weighed before and after discharging the gas and any mercury accompanying the gas was collected and weighed. The combined error on weighing is estimated as ±0.04 gram out of 1.35 gram for the gas of lowest density and 11.2 grams for the gas of highest density.

The presence of relatively large quantities of heptanes and heavier required refinements over the usual gas analysis. The heptane-plus fractions were collected and weighed as a liquid. The density and molecular weight were measured if sufficient quantities were available.

A smooth curve relationship exists between the liquid density and molecular weight of the heptanes plus and was used if the data for either were lacking. It was found that there was a permanent hold-up in the fractionating column packing as high as 0.5 gram. Differences between the weight of gas out of the pycnometer and the weight of the gas accounted for in the analysis varied up to this quantity. Accordingly, the weight of the heptanes and heavier was taken as the difference between the pycnometer weight of the gas and the weight of the hydrocarbons of molecular weight lower than heptane.

A typical analysis of the saturated vapor is given in Table 1. The absence of isobutane is due to the method of blending a butane-free gas with the Arkansas crude[6]

TABLE 1.—*Typical Analysis of Vapor*

Pressure, 4310 Lb. per Sq. In. Absolute. Temperature, 250°F.

Compound	Mol Fraction	Critical Temperature, Deg. R	Critical Pressure, P_c, Lb. per Sq. In. Abs.	Mol Fraction $\times pT_c$	Mol Fraction $\times pP_c$	Mol Fraction × Mol Weight
Methane	0.8058	344	673	277.2	542.3	12.89
Ethane	0.0386	549	712	21.2	27.5	1.16
Propane	0.0117	666	617	7.8	7.2	0.51
Normal butane	0.0197	766	551	15.1	10.8	1.14
Isopentane	0.0170	829	483	14.1	8.2	1.22
Normal pentane	0.0280	846	485	23.7	13.6	2.01
Isohexanes	0.0123	900	451	11.1	5.5	1.06
Normal hexane	0.0148	914	435	13.5	6.4	1.27
Heptanes + heavier	0.0521	1132	360	59.0	18.7	7.24
	1.000			442.7	640.2	28.50

Heptanes and heavier: molecular weight, 139; specific gravity, $^{60}/_{60}$, 0.791.

$$\text{Gas gravity} = \frac{28.50}{28.96} = 0.985$$

$$P_R = \frac{P}{pP_c} = \frac{4310}{640.2} = 6.73$$

$$T_R = \frac{T}{pT_c} = \frac{250 + 460}{442.7} = 1.603 \qquad Z \text{ from Fig. 2} = 0.933$$

$$PV = NZRT \qquad N = \frac{W}{M} = \text{pounds divided by mol weight}$$

$$PV = \frac{WZRT}{M}$$

$$\text{Calculated density} = \text{lb. per cu. ft.} = \frac{W}{V} = \frac{PM}{ZRT} = \frac{4310 \times 28.50}{0.933 \times 10.71 \times 710} = 17.35 \text{ lb. per cu. ft.}$$

Experimental density = 0.277 × 62.43 = 17.29 lb. per cu. ft.

and varying quantities of natural gasoline[6] that contained normal butane but no isobutane. Data on the density and properties of 16 saturated vapors in equilibrium with a crude oil are given in Table 2.

PSEUDOCRITICAL CONDITIONS OF HEPTANES AND HEAVIER FRACTIONS

Computation of the pseudocritical temperature and pressure of a gas is given in Table 1. Because of the high content and high molecular weight of the heptanes and heavier fractions, the usual procedure of using the critical properties of heptanes or octanes for this fraction is no longer reliable.

TABLE 2.—*Properties of Saturated Gases*

Run No.[a]	Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Gravity, Air = 1	Mol Per Cent CH_4	Mol Per Cent C_7^+	Mol Wt. C_7^+	Density C_7^+ 60/60	Experimental Density, Gram per C.C.	Experimental Compressibility Factor Z
A-5	1,000	120	0.659	0.9200	0.0090	110[b]	0.742[b]	0.0564	0.870
A-41	1,600	120	0.671	0.9158	0.0124	110[b]	0.742[b]	0.097	0.826
A-1	3,185	120	0.766	0.8800	0.0303	131	0.775[b]	0.224	0.810
A-21	5,270	120	0.840	0.8588	0.0400	127	0.788	0.340	0.970
A-3	8,220	120	0.899	0.8440	0.0444	144	0.802	0.404	1.358
B-1	2,920	250	0.766	0.8750	0.0268	115[b]	0.753[b]	0.154	0.884
C-2	1,010	120	0.629	0.9345	0.0021	100[b]	0.725[b]	0.0556	0.852
C-1	2,880	120	0.736	0.8895	0.0180	113	0.750[b]	0.203	0.777
C-31	5,330	120	1.040	0.7995	0.0573	151	0.800	0.400	1.031
D-1	4,330	120	0.876	0.8340	0.0375	123	0.788	0.327	0.865
E-1	4,195	120	0.736	0.8920	0.0243	130[b]	0.771	0.261	0.879
F-1	3,185	250	0.915	0.8450	0.0495	130	0.768	0.192	0.925
F-2	4,310	250	0.985	0.8060	0.0521	139	0.791	0.277	0.931
F-3	5,530	250	1.070	0.7840	0.0588	157	0.808	0.349	1.031
G-2	3,485	35	0.926	0.8230	0.0434	128	0.765	0.383	0.737
G-3	4,970	35	1.074	0.7810	0.0631	145[b]	0.792	0.463	1.008

[a] Series A and B	7,000 cu. ft. gas per bbl. 50 vol. crude + 50 vol. gasoline.
Series C, F and G	3,500 cu. ft. gas per bbl. 50 vol. crude + 50 vol. gasoline.
Series D	7,000 cu. ft. gas per bbl. 25 vol. crude + 75 vol. gasoline.
Series E	7,000 cu. ft. gas per bbl. 75 vol. crude + 25 vol. gasoline.

[b] Estimated.

Natural gas: gravity = 0.596; CH_4, 93.20 per cent; C_2H_6, 4.25 per cent; C_3H_8, 1.61 per cent; N_2, 0.43 per cent; CO_2, 0.51 per cent.

Smith and Watson[10] reported a method of obtaining the pseudocritical pressure directly from liquid density and molecular weight. For the pseudocritical temperature, the molal average boiling point must be known in addition to the liquid density. The mean average boiling point[10] may be obtained from the density and molecular weight by a chart similar to that given by Egloff and Nelson (ref. 3, p. 235) and revised to be in agreement with Smith and Watson's newly defined boiling points. This mean average boiling point may be converted to the molal average from the knowledge of the initial boiling point of about 200°F. for the heptanes and heavier fraction. The molal average boiling point and gravity give the pseudocritical temperature by Smith and Watson's relationship.

The densities and molecular weights of heptanes and heavier of Table 2 have been used to compute the pseudocriticals shown in Fig. 1. It should be noted that the calculated values deviate somewhat from the normal paraffin curve of critical temperatures and pressures as a function of molecular weight. The difference between the calculated pseudocriticals and the criticals of the normal paraffin hydrocarbons is much smaller when using the molecular weight of the heptanes and heavier than when using the liquid density as the correlating factor. In no case would the critical properties of heptanes have been representative of the heptanes and heavier fraction. Since the data given are for saturated vapors, it is indicated that the molecular weight, liquid density, and boiling range if possible, should be measured for gases at equilibrium above 1000 lb. or with appreciable quantities of heptanes and heavier present.

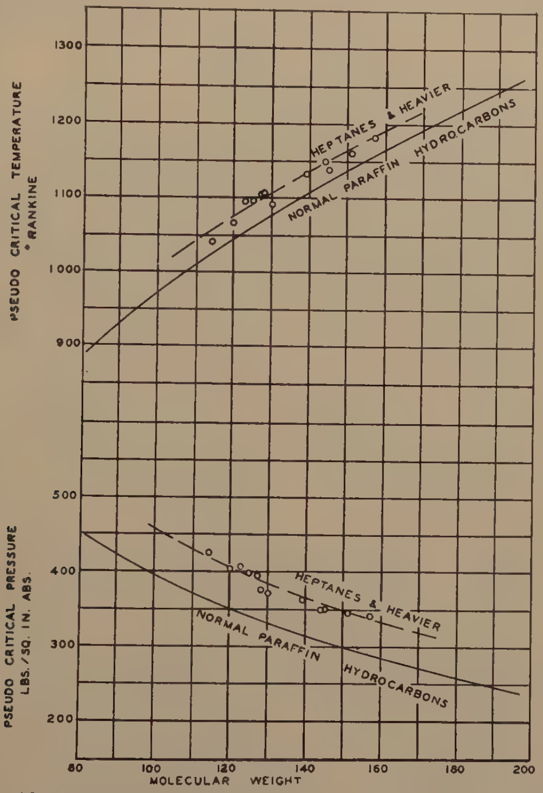

FIG. 1.—VARIATION OF PSEUDOCRITICALS WITH MOLECULAR WEIGHT.

COMPRESSIBILITY FACTORS FOR NATURAL GASES

The pycnometer density and the molecular weight of the gases, gas gravity referred to air, were used to compute the compressibility factors of the saturated vapors, Table 2. Excellent agreement was found between these values and those from the chart for natural gases[2] up to reduced pressures of about 5. At higher pressures, the data deviated from the natural-gas chart and were closer to the values from the chart based on pure methane. The measured density of the saturated vapors at 8220 lb. per sq. in. and 120°F. checked the computed density within the error of reading the methane chart.

The data on gaseous mixtures available to construct the chart for natural gases[2] were meager above 3000 lb., and the chart had been extended only to a reduced pressure of 8. Since it did not cover the pressure range of this investigation, and was shown to deviate consistently at pressures above reduced pressures of 5, a revised and extended plot was prepared (Fig. 2). This compressibility-factor chart is identical with the former chart[1,2] up to reduced pressures of 4. Using the data of Table 2 and the methane chart as a guide, Fig. 2 was drawn up to a reduced pressure of 15 or 9000 to 10,000 lb. per sq. inch.

RELATIONSHIPS OF GAS GRAVITY AND GAS DENSITY

The gas gravity, compared to air, and pseudocritical conditions gave a smooth relationship when compared with the curves for miscellaneous gases.[1] All gases whose pseudocritical temperatures and pressures fit these gravity curves have the same density for a temperature, pressure and gas gravity independent of composi-

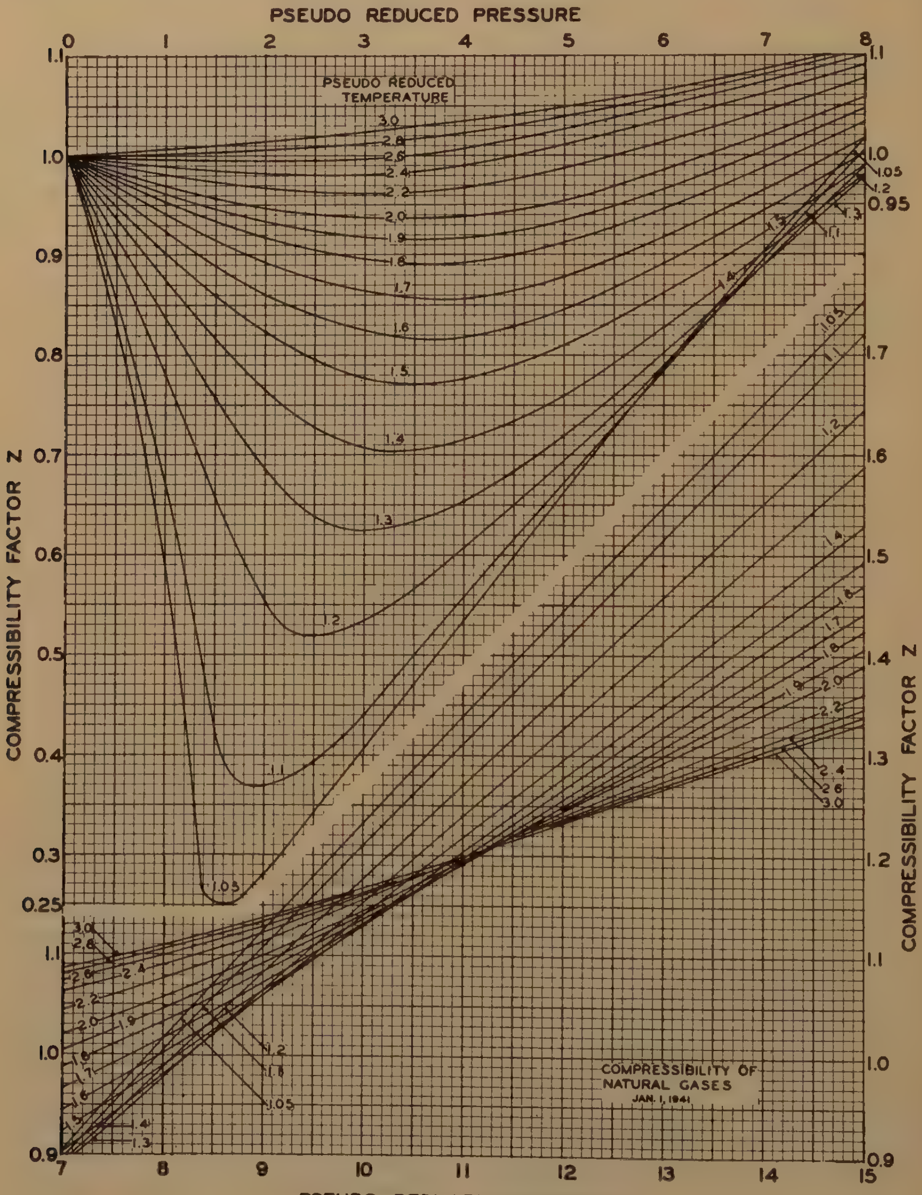

FIG. 2.—COMPRESSIBILITY FACTORS.

tion. This simplification makes it possible to construct charts giving gas density as a function of temperature, pressure, and gas gravity or molecular weight.

The hydrocarbon gases used to construct the curve of Fig. 3 contained more than 83 per cent of combined methane and heptanes and heavier fraction. Gases containing over 2 or 3 per cent of nitrogen or high concentrations of ethane, propane, and butanes deviate from the curves given. In all such cases, whenever the analysis is available, the pseudocritical conditions should be computed to establish the position of the curve on Fig. 3.

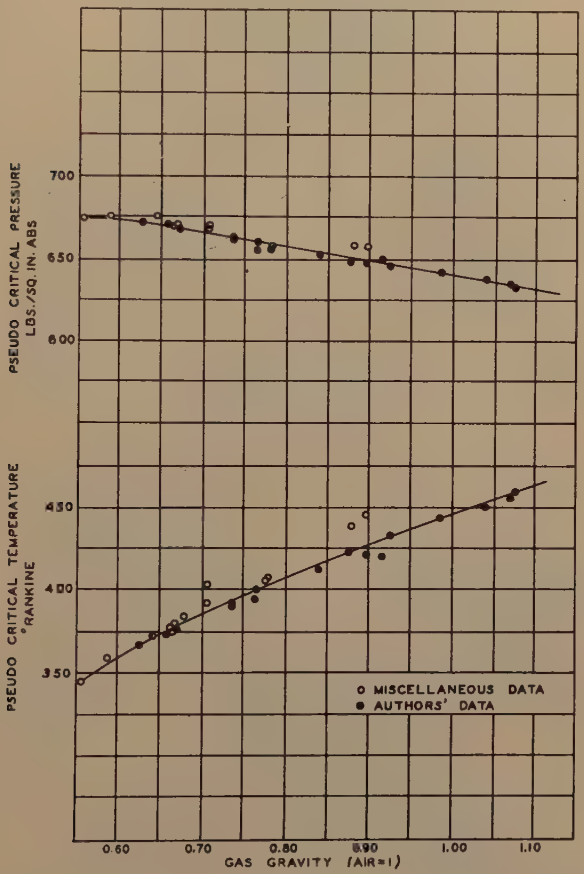

FIG. 3.—VARIATION OF PSEUDOCRITICALS WITH GAS GRAVITY.

For the gases represented by Fig. 3, density plots have been prepared. Fig. 4 gives the density of these gases with gravities (air = 1.0) from 0.6 to 0.8, and Fig. 5 from 0.9 to 1.1 for pressures from 100 to 10,000 lb. per sq. in. and temperatures from 0 to 300°F. Table 3 shows a comparison between the measured density, the density by the calculated pseudocriticals and Fig. 2, and the density from Figs. 4 and 5 for the authors' data. As would be expected, the densities computed from individual pseudocritical conditions and the compressibility-factor chart are superior to those from the gravity-density charts and are in

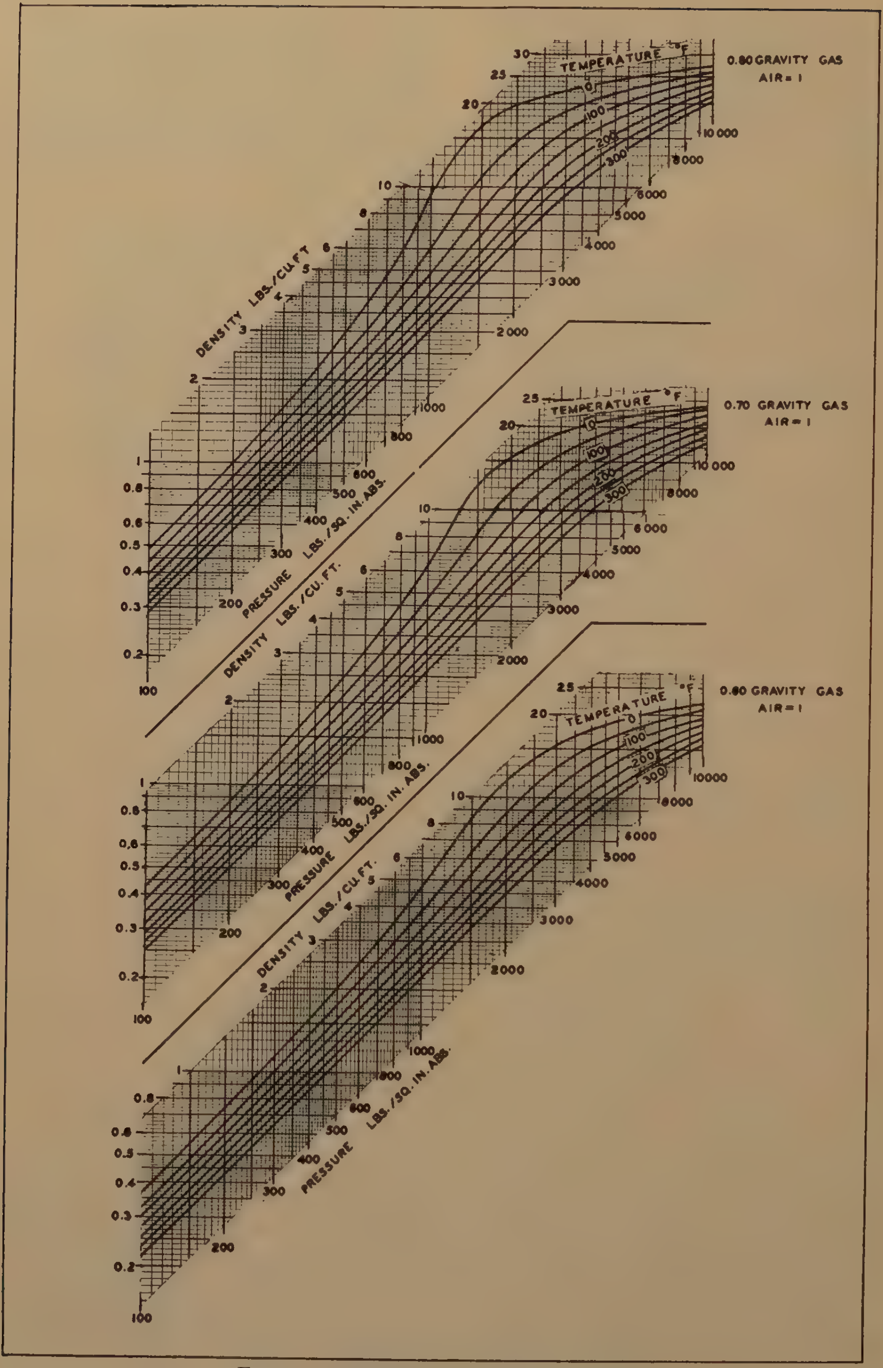

FIG. 4.—DENSITIES OF NATURAL GASES.

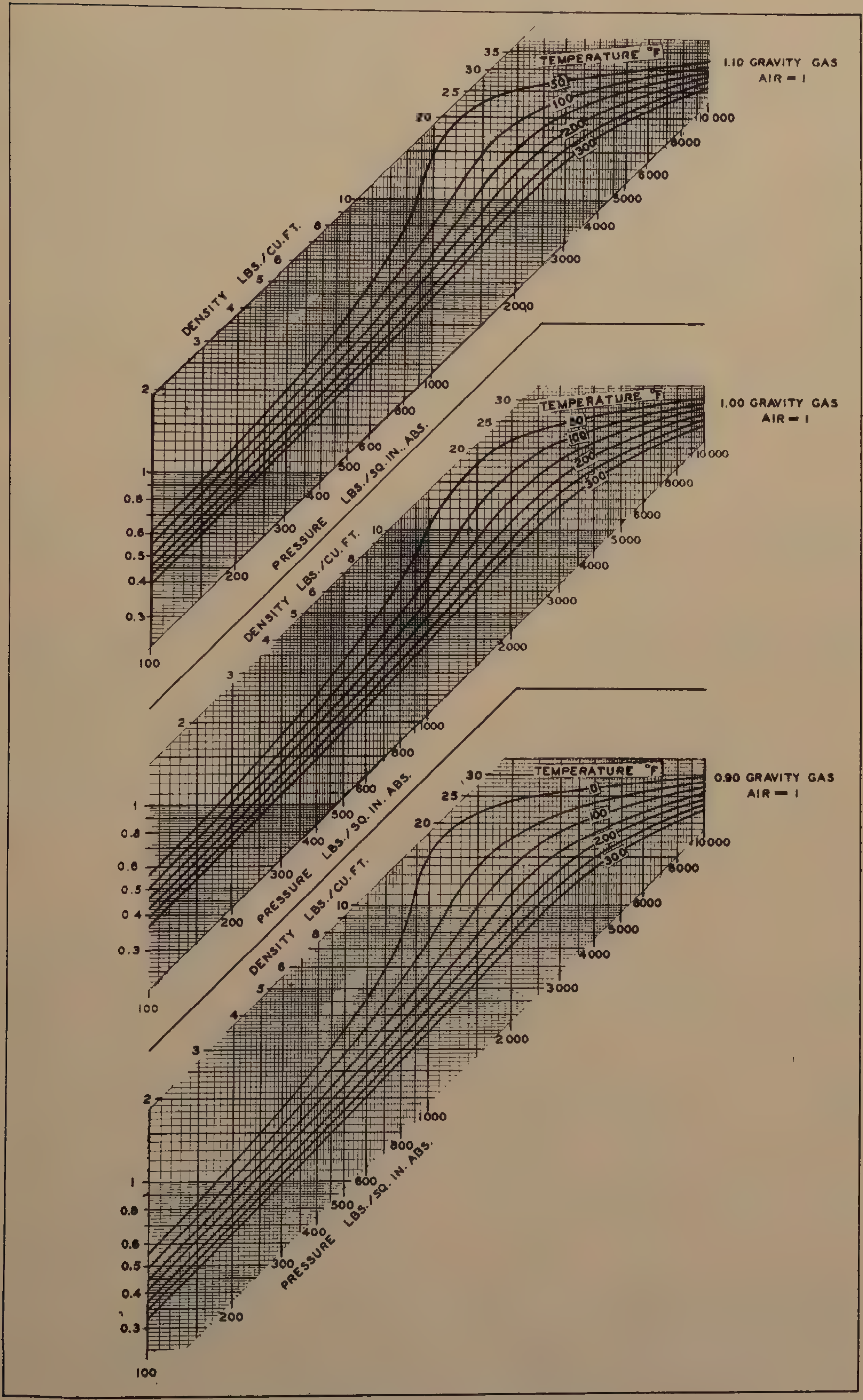

Fig. 5.—Densities of natural gases.

TABLE 3.—*Comparison of Experimental and Calculated Densities*

Run No.	Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Gravity, Air = 1	Pseudo Reduced Pressure	Pseudo Reduced Temperature	Experimental Density, Lb. per Cu. Ft.	Calculated Density, Fig. 2, Lb. per Cu. Ft.	Density, Fig. 4, Lb. per Cu. Ft.
A-5	1,000	120	0.659	1.50	1.55	3.52	3.50	3.55
A-41	1,600	120	0.671	2.42	1.54	6.06	6.12	6.15
A-1	3,185	120	0.766	4.87	1.47	14.0	14.4	14.8
A-2	5,270	120	0.840	8.09	1.41	21.2	20.8	21.0
A-3	8,220	120	0.899	12.7	1.37	25.2	25.2	25.3
B-1	2,920	250	0.766	4.44	1.77	9.61	9.55	9.59
C-2	1,010	120	0.629	1.50	1.59	3.47	3.31	3.39
C-1	2,880	120	0.736	4.35	1.48	12.7	12.7	12.9
C-31	5,330	120	1.04	8.36	1.29	25.0	25.5	25.6
D-1	4,330	120	0.876	6.70	1.37	20.4	20.2	20.1
E-1	4,195	120	0.736	6.34	1.48	16.3	16.3	16.6
F-1	3,185	250	0.915	4.90	1.69	12.0	12.8	12.7
F-2	4,310	250	0.985	6.72	1.60	17.3	17.3	18.0
F-3	5,530	250	1.07	8.72	1.55	21.8	21.6	21.2
G-2	3,485	35	0.926	5.41	1.14	23.9	24.2	
G-3	4,970	35	1.074	7.86	1.08	28.9	28.6	

good agreement with the experimental values. However, for gases containing less than 2 or 3 per cent nitrogen and more than 83 per cent of combined methane and heptanes and heavier, Fig. 4 is a convenient and quick method of obtaining densities for general engineering calculations.

TABLE 4.—*Comparison of Experimental and Calculated Densities of Rio Bravo Gas*

Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Experimental Density, Lb. per Cu. Ft.	Calculated Density, Fig. 2, Lb. per Cu. Ft.	Density, Fig. 4, Lb. per Cu. Ft.
500	100	1.74	1.74	1.75
1,000	100	3.78	3.76	3.75
2,000	100	8.54	8.46	8.45
3,500	100	13.9	13.9	13.8
5,000	100	16.8	16.9	16.8
500	190	1.44	1.44	1.44
1,000	190	3.00	3.02	3.02
2,000	190	6.32	6.38	6.40
3,500	190	10.8	10.9	10.8
5,000	190	14.0	14.0	14.0
500	280	1.24	1.25	1.25
1,000	280	2.52	2.55	2.55
2,000	280	5.16	5.24	5.25
3,500	280	8.82	8.94	9.02
5,000	280	11.8	11.8	11.8

The recent density data of Sage and Reamer[9] on the separator gas from the Rio Bravo field are compared with the computed densities and compressibility factors in Table 4. The agreement between computed and experimental results should be representative of gases of that type since the data were not used in any of the correlations.

A set of charts giving the density as a function of gas gravity, temperature, and pressure could be prepared for any series of gases that have a smooth relationship between gas gravity and pseudocritical conditions. Gases from a common source, such as covered by the data of this paper, or gases of similar composition may be expected to have such a relationship.

CONCLUSIONS

1. Density data have been reported on 16 saturated hydrocarbon vapors in the range of 35° to 250°F. and 1000 to 8220 pounds.

2. The compressibility-factor chart for natural gases has been revised and extended to 10,000 pounds.

3. The molecular weight, density and boiling range of the heptanes and heavier fraction has been shown to be an important part of the gas analysis for saturated vapors at high pressure and temperature.

4. Relationships have been presented by which the density of hydrocarbon gases containing more than 83 per cent of combined methane and heptanes plus may be obtained from temperature, pressure, and gas gravity (air = 1.0) directly.

ACKNOWLEDGMENT

The authors are indebted to the Humble Oil and Refining Co. for the natural gas, to the Phillips Petroleum Company for the crude oil, and to the Indian Territory Illuminating Oil Co. for the natural gasoline used in the investigation.

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Natural Gas Hydrates

By Don B. Carson* and Donald L. Katz,† Member A.I.M.E.

(Dallas Meeting, October 1941)

Natural gases under pressure form crystalline hydrates with water. Experimental data are reported on four-phase equilibrium for the methane-propane-water, methane-pentane-water, and methane-hexane-water systems. Temperatures and pressures for equilibrium between gas, water-rich liquid, hydrocarbon-rich liquid, and hydrate were measured, as well as the percentages of methane and propane in the hydrate. The data indicate that natural gas hydrate behaves as a solid solution and that pentanes and heavier hydrocarbons do not enter into the solid phase. Vapor-solid equilibrium constants are presented that permit the approximation of the conditions for hydrate formation, from the composition of a gas.

Introduction

Natural gas hydrates have been the object of considerable research in recent years, because of the trouble they have caused in the natural-gas and natural-gasoline industries. Natural gas hydrates are white crystalline compounds of water and gas, which, under pressure, exist at temperatures considerably above the freezing point of water. Because of the relatively high temperatures at which the hydrates exist, they become a nuisance in high-pressure gas operations where water is present, since their formation causes partial or complete plugging of valves and pipes. From a practical standpoint, the trouble incident to hydrate formation has been solved by dehydration of the gas before it enters the plant or pipe line, or by other remedial measures.

Extensive work on gas hydrates in the latter part of the nineteenth century, by Villard[1] and others, gave data on methane hydrate and on ethane hydrate. Schroeder summarized these theoretical studies.[2] Hammerschmidt[3] introduced the information on gas hydrates to the gas industry and Deaton and Frost[4–6] gathered a considerable number of data on the behavior of natural gas hydrates. Recent papers[7,8] have extended both the data and the theory of these hydrates.

At present, data are available on temperatures and pressures of hydrate formation for pure methane, ethane, propane, *n*-butane, methane-ethane mixtures, methane-propane mixtures, methane-butane mixtures, and some 15 natural gases, all in the presence of excess water. However, up to the present time no method has been available for predicting the temperature at given pressures or the pressure at given temperatures at which natural gases will form hydrates if saturated with water. This paper presents data on the methane-propane-water, methane-pentane-water and methane-hexane water systems in four phases, one of which is the hydrate. The application of the phase rule to the methane-propane-water data proves that hydrates behave as solid solutions. The data of this paper and those in the literature were used to develop vapor-solid equilibrium constants,[8] which permit prediction of conditions of hydrate formation from the analysis of a natural gas.

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[1] References are at the end of the paper.

Experimental Measurements

The experimental data are limited to measurement of temperatures and pressures for hydrate formation and phase compositions using three-component systems in four phases—gas, hydrocarbon-rich liquid, water-rich liquid and hydrate or solid phase.

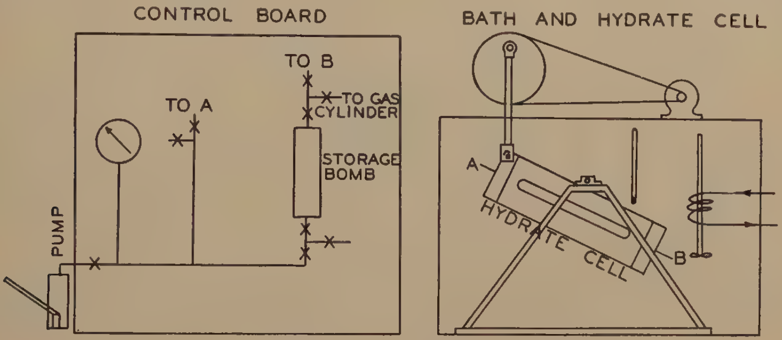

Fig. 1.—Apparatus for forming hydrates.

The apparatus (Fig. 1) consists mainly of a glass-windowed cell similar to that previously described[8] but which is capable of rotation for agitation of the contents of the cell. The temperature of the cell is indicated by the glass thermometer in the constant-temperature water bath surrounding it. The pressures were measured by a calibrated Bourdon tube gauge.

The materials used consisted of methane from the Buttonwillow field in California, reported to contain 0.3 per cent carbon dioxide and 99.7 per cent methane. The propane used in most of the experiments was c.p. propane from Phillips Petroleum Co. with negligible impurities but in the last eight runs of methane-propane-water the propane used contained 0.9 per cent unsaturates and similar amounts of other impurities. The pentanes were a cut from a distillation analysis of a butane-free naphtha. The hexane was c.p. *n*-hexane from Phillips Petroleum Co.

The data obtained were the pressures, at defined temperatures under which hydrates formed, with four phases in the cell. The presence of the hydrocarbon-rich liquid with two hydrocarbon components present, ensured a constant composition vapor at given temperatures and pressures, and the resulting hydrate was thus formed in equilibrium with constant composition vapor and liquids. The technique of obtaining hydrates with the two liquids and gas phase present was similar to that previously reported except that agitation was continuous. The data obtained are given in Table 1.

Table 1.—*Four-phase Equilibria Data for Methane-propane-water System*

Temperature, Deg. F.	Equilibrium Pressure, Lb. per Sq. In. Abs.	Mol Per Cent Propane in Hydrate, Dry Basis	Mol Per Cent Methane in Hydrate, Dry Basis
72.5	1052	39	61
69.7	774	53.6	46.4
65.5	521	58.8	41.2
61.9	403	73.6	26.4
58.5	310	74.1	25.9
65.3	534	51.2	48.8
51.2	177	86.5	13.5
64.2	478	69.5	30.5
51.6	187		
55.1	230		
61.9	408		
64.9	508		
69.8	832		
68.8	764	48.5	51.5
71.4	789		
56.6	256	76.5	23.5
54.1	263		

The composition of the hydrocarbons in the hydrate was measured for the methane-propane-water system. A large quantity of hydrate was formed in the presence of four phases; the hydrocarbon-rich liquid phase disappeared as the end of the hydrate formation was reached. Mercury was used to displace the gas and as much of the water-rich phase as possible, leaving the crystals with some adherent liquid. The hydrate was then decomposed and the gas evolved was analyzed for methane and propane by the gas-density method. The results are shown in Table 1.

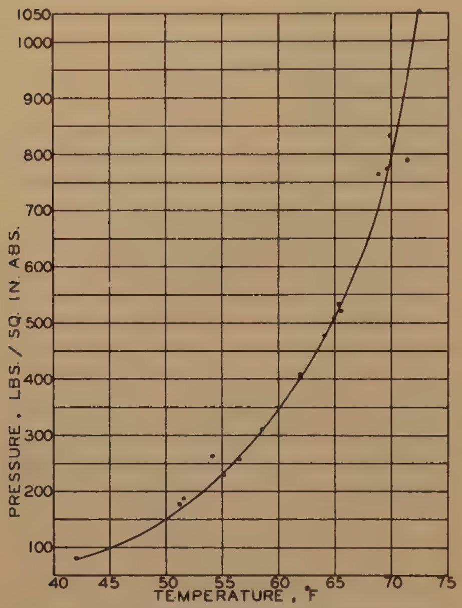

FIG. 2.—QUADRUPLE LOCUS FOR THE METHANE-PROPANE-WATER SYSTEM.

TABLE 2.—*Four-phase Equilibrium Data for Methane-pentane-water and Methane-hexane-water Systems*

Hydrocarbon Components	Temperature, Deg. F.	Equilibrium Pressure, Lb. per Sq. In. Abs.
Methane, *n*-hexane...	41.0	620
	41.6	622
Methane, *n*-hexane...	39.8	618
	46.2	861
	47.6	911
Methane, pentanes...	36.6	487
	38.2	519

Mixtures of pentanes with methane and *n*-hexane with methane were also brought into the four-phase equilibria using technique similar to that for the methane-propane-water system. Table 2 gives the data obtained for these mixtures with water in excess.

PHASE RULE PROOF OF SOLID SOLUTION

The phase rule states that the number of components plus two and minus the number of phases equals the degrees of freedom:

$$C + 2 - P = F \qquad [1]$$

The data on the methane-propane-water equilibria studied are plotted on Fig. 2 and show one degree of freedom. According to the phase rule, this system then comprises four phases, since there are three components. The gas, water-rich liquid and hydrocarbon-rich liquid phases were observed to be present in addition to the solid hydrates, which indicates that the solid hydrate is only one phase.

The hydrate-composition data are plotted on Fig. 3, giving the mol per cent propane on a water-free basis.

The continuous change in the concentration of the hydrocarbon constituents of the hydrate along the four-phase equilibrium line or quadruple locus indicates that the single-phase hydrate gradually changes in composition. This behavior is characteristic of solid solutions and indicates that natural gas hydrates are likely to be solid solutions.

COMPOSITION OF PHASES

Deaton and Frost[6] presented hydrate-formation conditions for various methane-propane mixtures in the presence of liquid water. These measurements were made with three phases at equilibrium—gas, water-rich liquid and hydrate. This information and the data on the methane-propane system[9] were used to construct Fig. 4, which shows the intersection of vapor compositions in equilibrium with

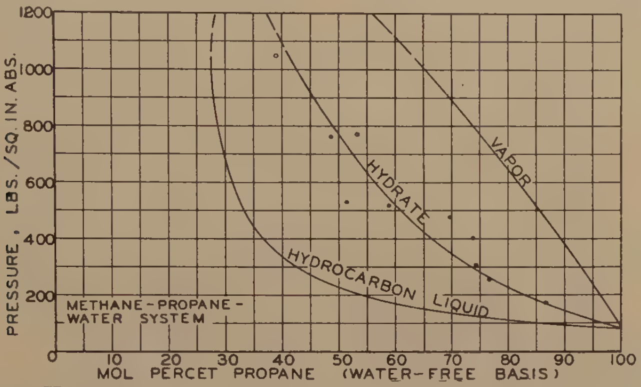

FIG. 3.—HYDROCARBON-PHASE COMPOSITIONS FOR FOUR-PHASE EQUILIBRIUM.

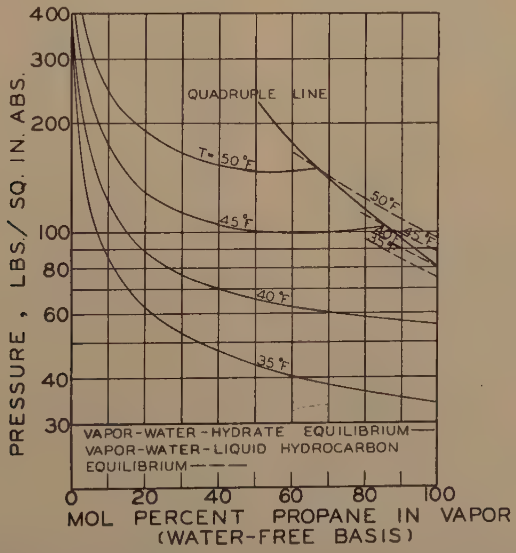

FIG. 4.—PREDICTION OF QUADRUPLE LOCUS FOR METHANE-PROPANE-WATER SYSTEM.

hydrate and in equilibrium with hydrocarbon liquid. These intersections are the four-phase equilibria points if it is assumed that the effect of water on the methane-propane vapor-liquid equilibrium reported by Sage, Lacey and Schaafsma[9] at these temperatures and pressures is negligible. The quadruple locus of Fig. 2 has been placed on Fig. 4, and gives a smooth extrapolation of the vapor-liquid equilibria curves. Chaddock reports[10] that the presence of a water-rich liquid phase with pure propane increases the vapor-liquid equilibrium pressure from 171 lb. only to 179 lb. per sq. in. abs. at 90°F. These two observations indicate that the presence of a water-rich liquid has little effect on the vapor-liquid equilibrium at the indicated temperatures. At least, the change in the ratio of the hydrocarbon compositions because of the presence of the water may be slight. On this basis, the data on the liquid-vapor equilibrium[9] have been placed on Fig. 3 and used as the dry compositions of the vapor and hydrocarbon-rich liquid in the four-phase equilibria.

The scattering of the points on the hydrate compositions (Fig. 3) probably is due to incomplete separation of the phases when the gas and liquid phases were removed from the cell.

Absence of Pentane and Hexane Hydrates

Since extrapolation of the trend of formation of ethane, propane, and *n*-butane hydrates indicates that the temperatures at which pure pentane would be expected to form hydrate are below 32°F., no data on pentane or hexane hydrates are obtainable by the usual procedure. If pentane forms a hydrate, mixtures of methane and pentane should form hydrate at temperatures above 32°F. The addition of ethane, propane and the butanes to methane lowers the pressure for hydrate formation below that required for pure methane at the same temperature. This change in equilibrium pressure is accompanied by the change in hydrate composition from pure methane and water to a solid solution of both hydrocarbons and water.

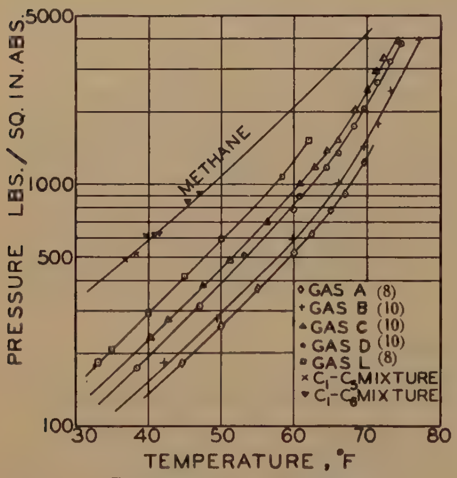

Fig. 5.—Conditions for formation of natural gas hydrates.

The data on methane-pentanes-water and methane-*n*-hexane-water of Table 2 when plotted fall along the curve for pure methane (Fig. 5). This indicates that paraffin hydrocarbons boiling above *n*-butane may not form hydrates. The data of Deaton and Frost[7] on binary hydrocarbon mixtures have been plotted on Fig. 6 to show the effect of constituents other than methane. The hydrate-formation pressure at 35°F. for the mixtures is subtracted from 447 lb., the value for pure methane, and this difference is plotted as a function of the concentration of the other constituent. The deviation increases from ethane to propane to isobutane but decreases to *n*-butane. It should be noted that the equilibrium pressure for the 0.8 per cent *n*-butane concentration was reported to be the same as for pure methane. Since the concentration of isopentane or *n*-pentane, in the vapor never exceeded 1.5 per cent, complete proof of the inability of pentane to form hydrate at high pressures with higher concentrations is lacking. However, the trend from ethane to *n*-butane is such that there is a distinct possibility that pentane does not enter into the hydrate crystal structure.

Equilibrium Constants to Predict Hydrate Formation

The substantiation that natural-gas hydrates are solid solutions and the hydrate-composition data given justify an elaboration of the vapor-solid equilibrium constant concept previously proposed.[8] These constants permit computation of the hydrate-formation conditions from the analysis of the gas, which is the desired correlation. The vapor-solid equilibrium constant, K_{v-s}, is defined by equation 2, and considers only the hydrocarbon portion of the vapor and solid phases. These vapor-solid equilibrium constants may be

$$K_{v-s} = \frac{y}{z} = \frac{\text{mol fraction of a hydrocarbon in vapor (dry basis)}}{\text{mol fraction of a hydrocarbon in hydrate (dry basis)}} \quad [2]$$

used in a manner similar to that for vapor-liquid equilibrium constants, computing hydrate-formation temperature or pressures instead of dew-point temperatures and pressures, and so forth.

In obtaining the vapor-solid equilibrium-constant chart for methane (Fig. 7), three sources of data were used. The points where $K = 1$ are from the hydrate-formation curve for pure methane.[6,7] One experimental K was available for methane for each pressure from the present data (Fig. 3). Hammerschmidt[3] reported the composition of a pipe-line gas and a gas

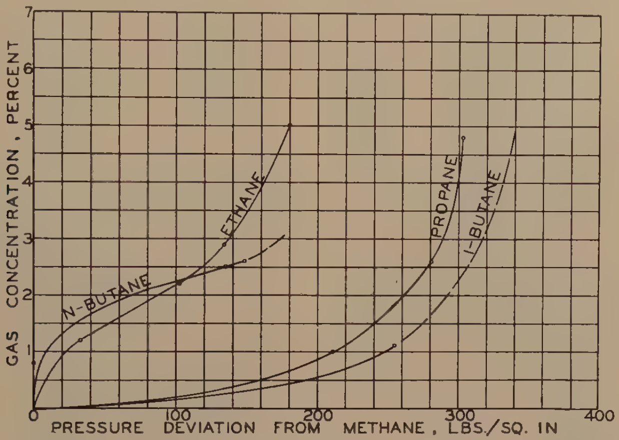

FIG. 6.—EFFECT OF HEAVIER COMPONENT ON HYDRATE FORMATION AT 35°F.

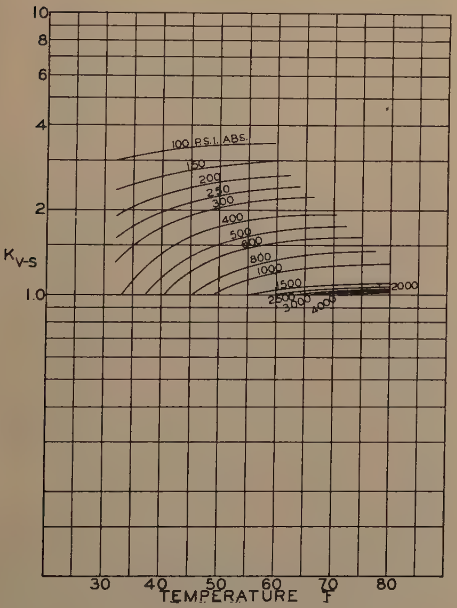

FIG. 7.—TENTATIVE K_{v-s} FOR METHANE.

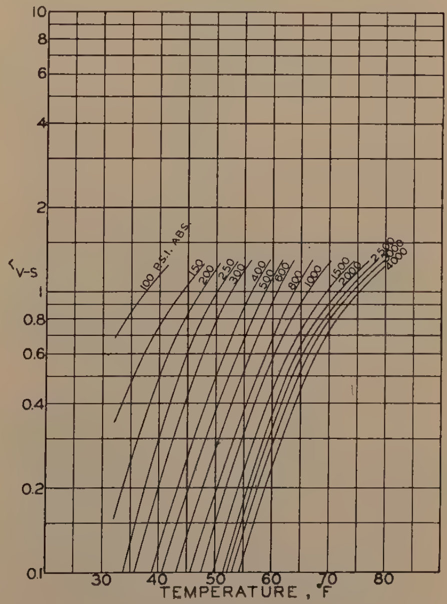

FIG. 8.—TENTATIVE K_{v-s} FOR ETHANE.

resulting from decomposition of a hydrate formed at 600 lb. per sq. in., giving K for methane at this pressure. Using these points, the K-curve for methane at 600 lb. per sq. in. was drawn, and curves for other pressures were drawn in symmetrically. By extrapolation, the range of pressures covered was expanded.

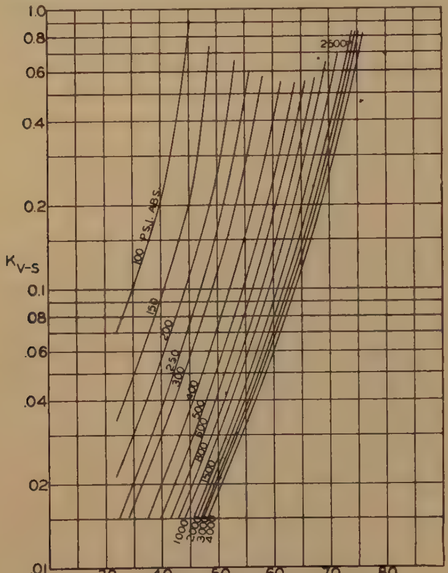

FIG. 9.—TENTATIVE K_{v-s} FOR PROPANE.

The equilibrium constants for ethane, propane, and isobutane next were calculated by using the binary hydrocarbon-mixture data for methane and these several components.[6] The relationship used in this calculation is $\sum \frac{y}{K}$ must equal unity at conditions of hydrate formation. The equilibrium constants shown in Figs. 8, 9 and 10 were obtained in this manner.

In the use of the equilibrium constants to calculate hydrate-formation conditions for some temperature, assumptions are made as to the pressure until $\sum \frac{y}{K} = 1$ for all the components. All components heavier than the butanes, including nitrogen, have a vapor-solid equilibrium constant of infinity, since they are not known to form hydrates. Fig. 6 shows that the hydrate properties of n-butane in natural-gas mixtures are close to those of ethane, and since there are few data on n-butane-methane mixtures, the equilibrium constant for n-butane is taken as equal to that for ethane. This assumption involves considerable error if the n-butane concentration in the gas is high. Carbon dioxide and hydrogen sulphide form hydrates with water in the pure state and when present in a gaseous mixture may be expected to enter the solid solution. Examination of data on the pure constituents indicates carbon dioxide equilibrium constants might lie halfway between ethane and methane while hydrogen sulphide may be similar to isobutane in its tendency to form hydrates. In the absence of data, the use of such equivalents is recommended for low concentrations.

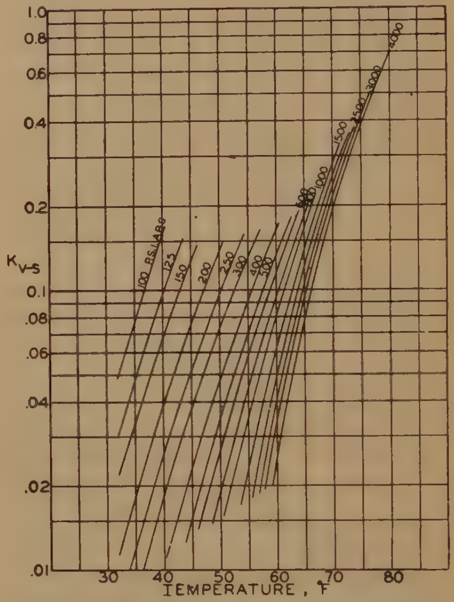

FIG. 10.—TENTATIVE K_{v-s} FOR ISOBUTANE.

It is appreciated that the assumptions and extrapolations used to prepare the equilibrium-constant charts might leave considerable doubt as to their reliability. The use of these charts to predict the hydrate-formation conditions of natural gases and comparison with experimental conditions will evaluate their accuracy and utility. Table 3 gives the comparison of computed and experimental pressures for 10 natural gases from the literature.

TABLE 3.—*Comparison of Calculated with Experimental Conditions for Hydrate Formation*

Gas	Investigator	Reference	Temperature, Deg. F.	Pressure at Which Hydrate Formed, Lb. per Sq. In. Abs.	
				Calculated	Experimental
1-B	Wilcox	8	40	156	156
			50	309	296
			60	677	600
			67	1,273	1,090
			75	3,620	3,000
2-C	Wilcox	8	40	242	231
			50	482	448
			60	1,017	935
			70	2,410	2,430
			74	over 4,000	4,000
3-D	Wilcox	8	40	186	193
			50	369	388
			60	796	815
			70	1,915	2,170
			74	3,380	3,580
4-B	Deaton and Frost	5	40	105	117
			50	223	240
5-C	Deaton and Frost	5	40	150	140
			50	300	280
6-D	Deaton and Frost	5	40	168	166
			50	343	325
7-E	Deaton and Frost	5	35	126	125
			45	242	248
			55	507	505
8-F	Deaton and Frost	5	40	180	182
			50	367	365
9-G	Deaton and Frost (Hammerschmidt)	3	40	181	210
			50	365	415
10-I	Deaton and Frost	5	40	250	295
			50	495	590
			60	1,053	1,180

Table 4 gives a typical calculation of the pressure at which hydrate forms when the given gas is in equilibrium with liquid water at 50°F.

The discrepancy between computed and experimental pressures in Table 3 may be caused by incorrect equilibrium constants or by inaccurate analyses of the gas. The calculation shows a high sensitivity to the propane and butane concentration. The presence of plus and minus errors indicates that the constants are a fair representation of the data available.

TABLE 4.—*Calculation of Pressure for Hydrate Formation at 50°F.*

Component	Mol Fraction in Gas	K at 300 Lb. per Sq. In.	y/K	K at 350 Lb. per Sq. In.	y/K
Methane..	0.784	2.04	0.384	1.90	0.412
Ethane....	0.060	0.79	0.076	0.63	0.0953
Propane...	0.036	0.113	0.318	0.09	0.400
i-butane...	0.005	0.0725	0.069	0.06	0.0834
n-butane..	0.019	0.79	0.024	0.63	0.0302
Nitrogen..	0.094	infinity	0.000	infinity	0.0000
Carbon dioxide...	0.002	1.41[a]	0.0014	1.26	0.0016
	1.000		0.8724		1.0225

Interpolating linearly, $y/K = 1.0$ at 343 lb. per sq. in. absolute.

The experimentally observed hydrate-formation pressure at 50°F. was 325 lb. per sq. in. abs.

[a] Taken as average of methane and ethane.

ACKNOWLEDGMENTS

The Southern California Gas Co. furnished the methane and Phillips Petroleum Co. furnished the propane and hexane used. Mr. Richard Rosencranz assisted in construction of the apparatus and took some of the preliminary measurements.

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DISCUSSION

(*R. O. Garrett presiding*)

E. C. HAMMERSCHMIDT,* Fritch, Texas.—The authors point out that the use of the equilibria constant charts to predict the hydrate-formation conditions of natural gas in comparison with experimental conditions will evaluate their accuracy and utility. Additional data on four different gases are presented in Table 5 as a supplement to Table 3. The data on gas H were taken from reference 5. The hydrate-formation experimental data of gas M were obtained from gasoline-plant vent vapors on Jan. 9, 1939, whereas the sample for the analysis of the vent vapors was not taken until May 31, 1939. For this reason, the data on gas M might be somewhat questionable, although the operating conditions of the gasoline plant were the same on both dates. Gas L is a gasoline-plant absorber-inlet gas, sampled on Oct. 25, 1938, and gas K is a gasoline-plant absorber-inlet gas sampled on Dec. 5, 1939.

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* Texoma Natural Gas Co.

TABLE 5.—*Data on Four Different Gases*

Gas	K	L	M	H
Carbon dioxide				0.8
Methane	84.52	77.53	39.83	67.4
Ethane	4.30	5.91	18.07	3.7
Propane	3.33	4.85	30.15	1.9
iso-butene	0.47	0.46	3.60	0.5
n-butene	0.69	1.02	8.27	0.7
Pentane plus	0.08	0.62	0.08	
Nitrogen	6.61	9.61		25.0
British thermal units	1,047	1,076	1,879	827
Experimental hydrate-formation pressure at 40°F., lb. per sq. in.	180	170	110	230
Calculated hydrate-formation pressure at 40°F., lb. per sq. in.	173	148	<100	218
Experimental hydrate-formation pressure at 50°F., lb. per sq. in.	390	350	243	465
Calculated hydrate-formation pressure at 50°F., lb. per sq. in.	358	317	165	469

Excluding gas M, the average deviation of the calculated hydrate-formation pressure from the experimental data is 7.2 per cent. This average includes the 30 points in Table 3 together with the six additional points of Table 5. Of the 36 points, the maximum deviation is 20.7 per cent and the minimum deviation is zero. Comparing the hydrate-formation pressures of the richest gas in reference 5 (gas C, Kettleman Hills, Calif.) with the leanest gas (gas I, Cayuga, Tex.), the deviation of gas C from gas I is approximately 50 per cent. The deviation between pure methane and pure ethane is even greater, so that an attempt to use hydrate-formation-pressure curves of some particular gas for a gas whose hydrate-formation pressure is unknown could lead to much greater errors than the average percentage deviation that is shown by the calculated hydrate-formation pressures. It appears therefore that the authors have provided a practical and relatively simple method of estimating the hydrate-forming pressures. However, the large deviation between the experimental and calculated data of gas M indicates that calculated hydrate-formation pressures should be used cautiously in connection with a rich gas of this type until more data become available.

Density of Crude Oils Saturated with Natural Gas

By Marshall B. Standing* and Donald L. Katz,† Member A.I.M.E.

(Los Angeles Meeting, October 1941)

Density data are reported on 15 saturated hydrocarbon liquids in the range of 35° to 250°F. and 1000 to 8220 lb. per sq. in. The apparent liquid densities of methane and ethane are shown to vary with the density of the system in which they are present. A method is proposed whereby the densities of liquid hydrocarbon mixtures containing both methane and ethane in solution may be computed at elevated temperature and pressures within the accuracy of usual engineering computations. A method of computing the shrinkage of crude oils based upon the gas-oil ratio, gas analysis, and crude gravity is outlined.

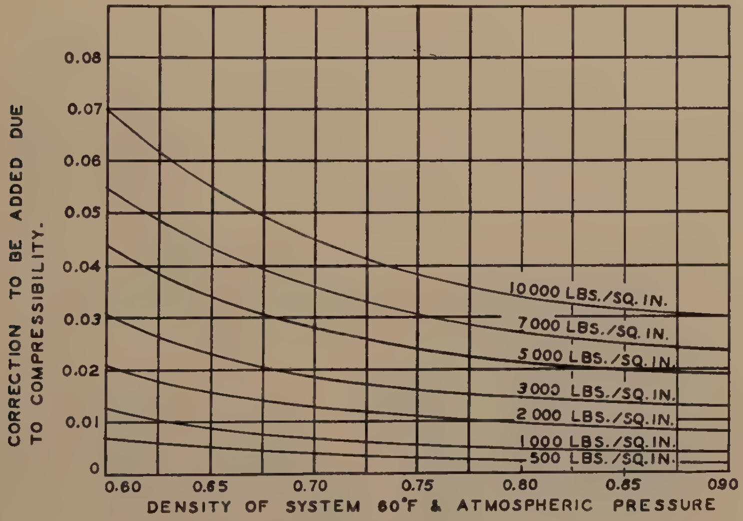

Fig. 1.—Correction for compressibility of liquids.

Introduction

The densities of naturally occurring liquid hydrocarbon mixtures are important in many petroleum engineering computations. Calculation of the shrinkage of a subsurface sample of crude oil as the natural gas is evolved is one example of the use of liquid-density data.

Sage, Hicks, and Lacey[5] have presented a method of computing the density of hydrocarbon liquid mixtures based on partial molal volumes. Katz[1] has indicated a method based on the principle of additive

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[5] References are at the end of the paper.

volumes of the components and using apparent densities for methane and ethane. The former method does not cover the necessary pressure and composition range, while the latter is inaccurate because of the values of the apparent densities used.

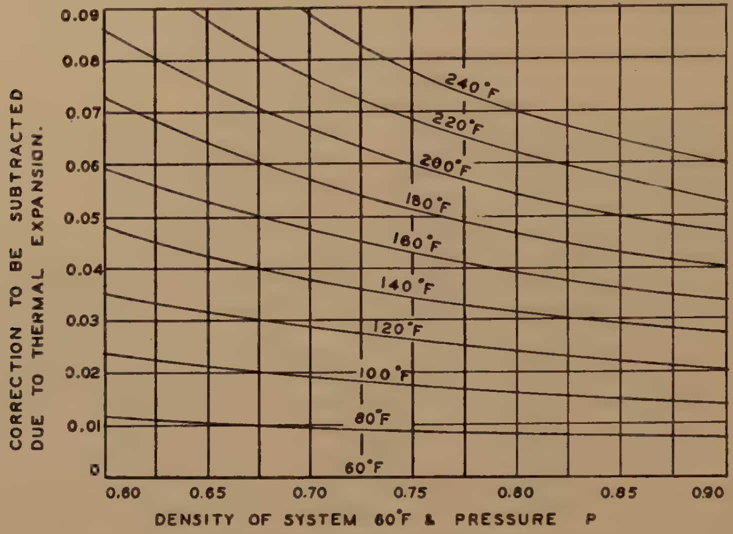

FIG. 2.—CORRECTION FOR THERMAL EXPANSION OF LIQUIDS.

This paper reports the density of 15 saturated crude oils in equilibrium with natural gas at pressures up to 8220 lb. per sq. in. The apparent-density method of computing liquid densities has been revised and applied to the data presented, giving a maximum error of 4 per cent and an average error of 1.2 per cent of the experimental liquid density.

DATA OBTAINED

In the process of obtaining equilibrium data on mixtures of natural gas and crude oils, the densities and analyses of the coexisting phases were obtained. The data were in the temperature and pressure range of 35° to 250°F. and 1000 to 8220 lb. per sq. in. The gas densities and methods of computation were reported in an earlier paper.[7]

The liquid phase in equilibrium with the natural gas was transferred by mercury displacement at constant temperature and pressure from the equilibrium cell into pycnometers of 25 c.c. capacity. The contents of the pycnometers were discharged into a small topping column from which the components lighter than heptane could be distilled into a low-temperature column for fractionation. The residue from the topping column and any material boiling above the hexanes were combined as "heptanes and heavier." The pycnometers

TABLE 1.—*Analysis of Typical Liquid*
5330 Lb. per Sq. In. Abs., 120°F.

Component	Mol Fraction	Weight Fraction
Methane	0.5641	0.1091
Ethane	0.0351	0.0127
Propane	0.0137	0.0073
Normal butane	0.0244	0.0171
Isopentane	0.0247	0.0215
Normal pentane	0.0326	0.0284
Isohexane	0.0188	0.0195
Normal hexane	0.0246	0.0256
Heptane and heavier[a]	0.2620	0.7588
	1.000	1.000

[a] Density, grams per c.c., 0.881; molecular weight, 240.

TABLE 2.—*Properties of the Saturated Liquids*

Run No.	Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Mol Fraction		Mol Wt., C_7^+	Density, Grams per C.C.	
			CH_4	C_7^+		C_7^+ at 60°F.	Experimental, at Temperature and Pressure
A-4	1,600	120	0.2965	0.3468	196	0.850	0.702
A-1	3,185	120	0.4385	0.3186	240	0.863	0.696
A-2	5,270	120	0.5558	0.2760	279	0.904	0.745
A-3	8,220	120	0.6076	0.2565	356	0.954	0.814
B-1	2,915	250	0.4158	0.3874	231	0.870	0.697
C-2	1,010	120	0.2234	0.4200	186	0.836	0.716
C-1	2,880	120	0.4850	0.2592	186	0.844	0.652
C-3	5,330	120	0.5641	0.2620	240	0.881	0.712
F-1	3,185	250	0.4470	0.3500	216	0.862	0.654
F-2	4,315	250	0.5124	0.2590	256[a]	0.888	0.657
F-3	5,530	250	0.5766	0.2370	290[a]	0.912	0.677
G-2	3,485	35	0.5700	0.2000	215[a]	0.863	0.679
G-3	4,970	35	0.5799	0.2182	315[a]	0.903	0.766
D-1	4,330	120	0.5260	0.2560	268	0.893	0.731
E-1	4,195	120	0.5178	0.3312	242	0.877	0.753

[a] Estimated from plot of specific gravity vs. mol weight.

were weighed before and after the liquid was discharged and any mercury accompanying the fluid to the topping column was collected and weighed. The density of the heptanes and heavier fraction was determined with small glass pycnometers and the molecular weight was determined by the cryoscopic method, using water-saturated benzene as a solvent.

TABLE 3.—*Calculation of Density of Rio Bravo Trap Liquid*

Component	Weight Fraction	Density, Grams per C.C., 60°F., 1 Atm.	Cubic Centimeters per Gram Sample
Methane	0.01499		
Ethane	0.01448		
Propane	0.03395	0.510	0.0665
i-butane	0.01151	0.564	0.0204
n-butane	0.04860	0.584	0.0832
i-pentane	0.01334	0.625	0.0213
n-pentane	0.01649	0.631	0.0261
Hexanes and heavier	0.84664	0.849	0.9972
	0.97053		1.2147

Density of propane and heavier $\frac{0.97053}{1.2147} = 0.799$

Weight fraction ethane in ethane and heavier $= \frac{0.01448}{0.98501} = 0.0147$

Fig. 4 for 0.799 density at 1.47 wt. per cent ethane gives 0.791 gram per c.c. for ethane and heavier.

Fig. 4 for 0.791 density at 1.50 wt. per cent methane gives 0.776 gram per c.c. as density at 60°F. and one atmosphere. Correction of 0.776 gram per c.c. by Fig. 1 to density at 1000 lb. gives 0.781 gram per c.c. Correction of 0.781 grams per c.c. from 60°F. to 100°F., Fig. 2, gives 0.765 gram per c.c.

TABLE 4.—*Comparison Experimental and Calculated Densities, Rio Bravo Trap Liquid*

Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	Density, Grams per C.C.	
		Experimental[6]	Calculated
1,000	100	0.770	0.765
2,000	100	0.778	0.770
3,000	100	0.785	0.775
1,000	190	0.731	0.729
2,000	190	0.732	0.734
3,000	190	0.745	0.745

Analysis of a typical saturated liquid is given in Table 1. The absence of isobutane is due to the method of blending a butane-free natural gas with the Arkansas crude[2] and varying quantities of the natural gasoline,[2] both of which were devoid of isobutane. Data on the density and properties of the 15 saturated liquids are given in Table 2.

EFFECT OF TEMPERATURE AND PRESSURE ON LIQUID DENSITY

Any method of computing the density of hydrocarbon liquids requires corrections to the density for pressure and temperature changes. Sage, Lacey and coworkers on A.P.I. Project No. 37 have amassed considerable data on the effect of temperature and pressure on the specific volume of a great variety of liquids. A survey of these and other data on liquid densities indicated that pressure corrections at 60°F. were essentially functions of the liquid density and that the thermal expansion of liquids was little affected by pressure.

Fig. 1 was prepared from the mass of data in the literature, and gives an additive correction to the density for increases in pressure. Minor differences occurred between the density changes with pressure for materials of the same density but were not regular enough to permit a more accurate relationship covering most hydrocarbon liquids.

TABLE 5.—*Comparison of Experimental and Calculated Densities of Saturated Crude Oils*

Run No.	Pressure, Lb. per Sq. In Abs.	Temperature, Deg. F.	Density, Grams per C.C.		
			Experimental	Calculated	Deviation Calculated from Experimental, Per Cent
A-4	1,600	120	0.702	0.709	+1.00
A-1	3,185	120	0.696	0.722	+4.02
A-2	5,270	120	0.745	0.751	+0.80
A-3	8,220	120	0.814	0.811	−0.37
B-1	2,915	250	0.697	0.700	+0.43
C-2	1,010	120	0.716	0.713	−0.42
C-1	2,880	120	0.652	0.649	−0.46
C-3	5,330	120	0.712	0.708	−0.56
F-1	3,185	250	0.654	0.668	+2.16
F-2	4,315	250	0.657	0.664	+1.06
F-3	5,530	250	0.677	0.681	+0.59
G-2	3,485	35	0.679	0.676	−0.44
G-3	4,970	35	0.766	0.756	−1.30
D-1	4,330	120	0.731	0.713	−1.64
E-1	4,195	120	0.753	0.736	−2.26
Algebraic average					+0.28
Numerical average					1.16

TABLE 6.—*Example Calculation of Shrinkage Factor Crescent Crude*

Given:

Gas liberated	814 cu. ft. per bbl. residual oil
Crude gravity (from U.S. Bureau of Mines)	41.7° A.P.I.
Saturation temperature	149°F.
Saturation pressure	2575 lb. per sq. in. abs.

GAS ANALYSIS

Component	Volume, Per Cent
Methane	75.33
Ethane	10.09
Propane	6.96
Butanes	5.58
Pentanes	1.56
Hexanes plus	0.48

CALCULATION OF SHRINKAGE

Component	Cu. Ft.	Mol. Wt.	Pounds	Liquid, Lb. per Cu. Ft., 60°F. and 14.7 Lb. per Sq. In.	Liquid Cu. Ft.
Methane	612.	16	25.8		
Ethane	82.0	30	6.5		
Propane	56.6	44	6.6	31.8	0.208
Butanes	45.4	58	6.9	36.1	0.191
Pentanes	12.7	72	2.4	39.2	0.061
Hexanes⁺	3.9	86	0.8	41.5	0.019
Crude oil	5.61		286.0	51.0	5.610
		Total	335.0		6.089
		Propane⁺	302.7		
		Ethane⁺	309.2		

Density of propane plus $= \frac{302.7}{6.089} = 49.8$ lb. per cu. ft. $= 0.799$ grams per c.c.

Weight per cent ethane $= \frac{6.5}{309.2} = 2.1$

Weight per cent methane $= \frac{25.8}{335.0} = 7.7$

From Fig. 4:
  Density of ethane plus = 0.789 gram per c.c.
  Density of methane plus = 0.712 gram per c.c.
From Figs. 1 and 2:
  Density of system at 60°F. and 2575 lb. = 0.727 gram per c.c.
  Density of system at 149°F. and 2575 lb. = 0.686 gram per c.c. = 42.8 lb. per cu. ft.

Volume of one barrel of crude and accompanying gas at 149°F. and 2575 lb. $= \frac{335.0}{42.8} = 7.82$ cu. ft.

Volume of dissolved gas $= 7.82 - 5.61 = 2.21$ cu. ft.

Shrinkage $= \frac{2.21}{5.61} = 39.4$ per cent based on residual oil.

Shrinkage reported by Lindsly = 40.7 per cent.

For computing the thermal expansion under pressure, the atmospheric pressure corrections may be used,[4] or Fig. 2, which is based primarily upon Sage and Lacey's data.

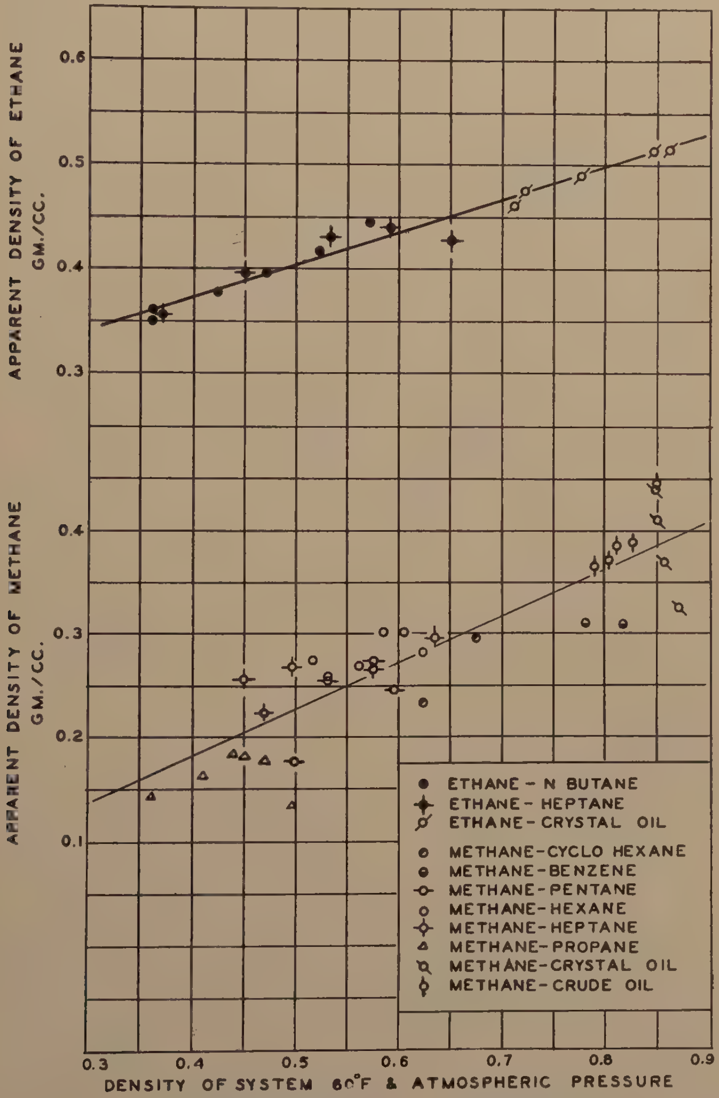

FIG. 3.—VARIATION OF APPARENT DENSITY OF METHANE AND ETHANE WITH DENSITY OF THE SYSTEM.

APPARENT DENSITIES OF METHANE AND ETHANE

It is known that the rule of additive volumes applies very well for pentane and hexane, and that the apparent density of methane and ethane dissolved in hydrocarbon liquids is a function of the system. Calculation of the apparent liquid density of methane and ethane after correcting the density of the mixture to 60°F. and one atmosphere pressure gave the relationship shown in Fig. 3. Since the systems did not contain both methane and ethane, the use of the liquid densities of the other constituents at 60°F.[1] and one atmosphere left the density of either methane or ethane as the only unknown. Fig. 4 is a plot of the densities of systems containing methane and ethane as a function of the density of the remainder of the system and concentration of the volatile hydrocarbon. This assumes that the presence of the ethane in systems containing methane does not change the methane curve of Fig. 3.

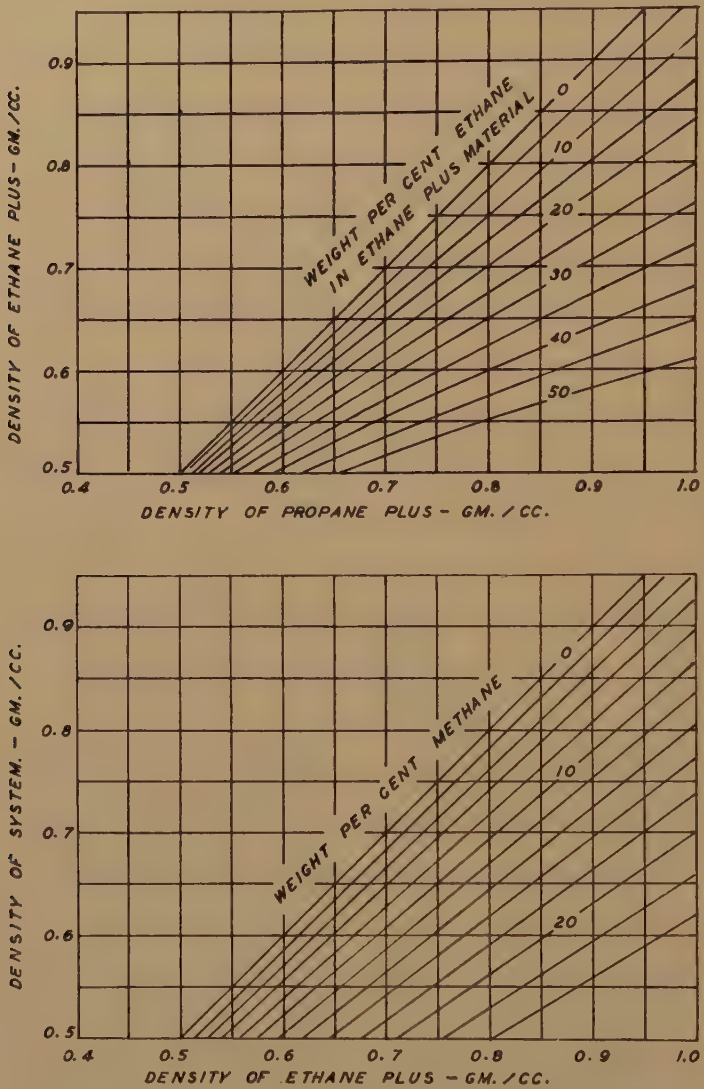

FIG. 4.—DENSITIES OF SYSTEMS CONTAINING METHANE AND ETHANE.

CALCULATION OF LIQUID DENSITY

The method of computing a liquid density is illustrated in Table 3, using the Rio Bravo trap liquid analysis.[6] The weights of components heavier than ethane are converted to volumes by dividing by the specific gravity or density of the component at 60°F. and one atmosphere. The volume and weight of this propane plus fraction gives its density at 60°F. and one atmosphere. Fig. 4 gives in turn the density including the ethane and then the methane. The resulting density at 60°F. and one atmosphere is a fictitious value, since the liquid cannot exist at these conditions. The correction for pressure must be made at 60°F. by Fig. 1 before correcting for thermal expansion by Fig. 2.

Table 4 shows the computed and experimental densities of the Rio Bravo trap liquid.[6] Table 5 gives similar information on the gas-saturated crude oils of Table 2. It should be noted that these liquids contained from 22 to 60 mol per cent methane. The maximum deviation between the calculated and experimental densities is 4.0 per cent, with a numerical average deviation of 1.16 per cent. Since none of these data were used in the apparent density correlation for methane and ethane, this agreement should be typical for crude oils.

APPLICATION TO SHRINKAGE CALCULATION

Among the calculations requiring a knowledge of the density of the liquid phase, or reservoir fluid if no gas cap is present, are those involving the estimation of reserves. The usual method of relating the volume of the crude oil as measured at the stock tank to the volume that it occupied with its dissolved gas at the reservoir conditions is by means of a shrinkage factor. This factor may be measured on a subsurface sample but may be computed from the analysis of the gas evolved from the reservoir liquid as it passed from the reservoir to the stock tank. Table 6 presents an example calculation of the shrinkage factor for the Crescent pool crude, using the data presented by Lindsly.[3]

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DISCUSSION

(*Carlton Beal presiding*)

M. G. ARTHUR,* Santa Fe Springs, Calif.—The accurate prediction of the volumetric behavior of naturally occurring hydrocarbon mixtures has been restricted by a lack of an abundance of published data on the properties of such systems at high temperatures and pressures. Although the densities of the gas and liquid phases were predictable to a fair degree of accuracy at states well below the critical temperatures and pressures, the methods and data did not permit an accurate prediction of densities at conditions near the criticals. Since many of the recently discovered petroleum reservoirs, and probably many of those to be discovered in the future, will exist at these high temperatures and pressures, any data correlating the volumetric behavior at such conditions are a valuable addition to the literature.

The methods reported by Messrs. Standing and Katz give results that check well with experimentally determined values and the methods are especially valuable if the results are as accurate for crude oils of different sources having different compositions of the hydrocarbons of greater molecular weight than the hexanes.

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* Union Oil Company of California.

Unsteady Flow of Gas through Porous Media

By Charles R. Hetherington,* D. T. MacRoberts† and R. L. Huntington,‡
Member A.I.M.E.

(Dallas Meeting, October 1941)

Since the equation of continuity governing transient flow of gases through porous media cannot be integrated mathematically into a simple usable expression free from series terms, empirical and approximate equations have been advanced relating cumulative production and future production rates from gas reservoirs with time. In order to check the accuracy of these empirical equations and to obtain an insight into the initial conditions pertinent to the solution of the fundamental equation of continuity, experimental work has been conducted on a vertical 2-in. tube, 91.6 ft. high, packed with unconsolidated Wilcox sand. The results presented in graphical form show the accuracy of the approximate relations.

Data from unsteady-flow runs on the 2-in. experimental tube are presented graphically, and are applied to obtain an equation for this specific case, and are offered as an aid in future investigations of this basic equation.

The close agreement between equations calculated for steady-state flow and the experiments indicates that the decline of actual gas reservoirs may be treated by an application of these equations without serious error.

Introduction

The steady-state flow of gas through a porous material—that is, flow wherein the boundary conditions do not vary with time—is subject to analytical solution. Muskat[1] has shown that the general differential equation is simply the La Place equation in P^2. Direct solutions may be at once obtained.

The unsteady state, on the other hand, is not analytically reducible. Since nearly all phenomena of practical interest in gas production involve flow in the unsteady rather than in the steady state, it has been necessary to derive approximate solutions to the general equation. The validity of such approximations has not hitherto been adequately tested.

In the experiments to be described a simple, closed, linear system is substituted for the real complex gas field. The general results, however, are independent of the geometry of the system. The problem studied is the rate of production, and the accompanying variations in pressure, when one end of a linear porous system is opened to the atmosphere and permitted to produce to exhaustion. An approximate solution to the general differential equation, based upon the assumption of an "infinite series of steady states," is then applied to the results to determine the validity of this method of dealing with actual reservoirs.

Theoretical Considerations

The fundamental differential equation governing the flow of a gas through a porous medium can be derived easily from the equation of continuity, Darcy's law, Boyle's law and a statement of the thermodynamic nature of the flow. For isothermal flow it is:

$$\frac{\partial^2 P^2}{\partial x^2} + \frac{\partial^2 P^2}{\partial y^2} + \frac{\partial^2 P^2}{\partial z^2} = \frac{2f\mu}{K}\frac{\partial P}{\partial T} \qquad [1]$$

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[1] References are at the end of the paper.

This second-order, nonlinear equation has no general solution. If, however, we assume that at any instant the flow closely approximates the steady state (right-hand side of Eq. 1 equal to zero) and further assume that the average pressure over the flowing system is negligibly different from the pressure at the external boundary, then, for the case where the pressure at the outlet of the system is small (approximately atmospheric), we may directly derive the equation for the cumulative production from the system:

$$Q = Q_0\left[1 - \left(\frac{1}{1 + \frac{(2N-1)C_0T}{Q_0}}\right)^{\frac{1}{2N-1}}\right] \qquad [2]$$

where the symbols have the following meanings:

Q = total quantity (volume) produced to time T.

Q_0 = initial quantity in reservoir.

C_0 = initial rate of flow (per unit of time T).

T = time.

N = experimental exponent of Eq. 3.

$$\frac{Q}{T} = a(P_s^2 - P_f^2)^N \qquad [3]$$

where:

P_s = pressure at the external boundary of the system.

P_f = pressure at outlet of system.

a = experimental constant.

Equation 3 is, of course, the "characteristic equation" of the "back-pressure" method of testing gas wells and can also be derived directly from the foregoing assumptions. The geometry of the system and the characteristics of the medium are absorbed in the constant a.

For the case where the outlet pressure is not small, the integrations become much more complex. If the outlet pressure is held constant and the flow is viscous and isothermal, the cumulative production is:

$$Q = \frac{(Q_0 - Q_f)\left(1 - e^{-\frac{2C_0Q_fT}{Q_0^2 - Q_f^2}}\right)}{1 - \left(\frac{Q_0 - Q_f}{Q_0 + Q_f}\right)e^{-\frac{2C_0Q_fT}{Q_0^2 - Q_f^2}}} \qquad [4]$$

where Q_f is the volume contained in the reservoir at the outlet pressure P_f. Conditions during these experiments did not conform to the assumptions outlined for Eq. 4 to hold.

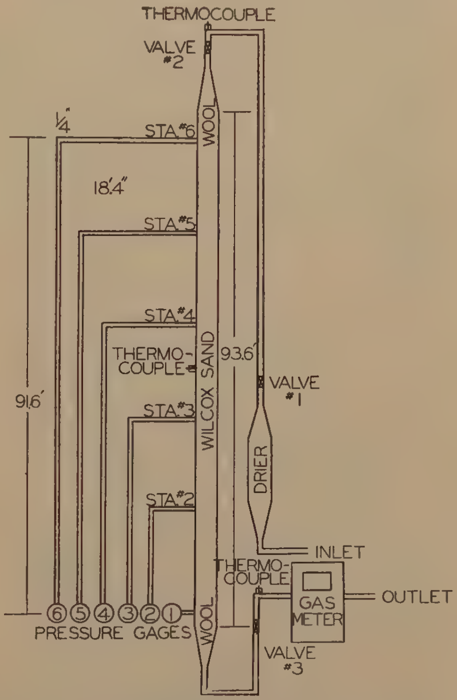

FIG. 1.—DIAGRAMMATIC SKETCH OF EXPERIMENTAL ASSEMBLY.

APPARATUS

The apparatus used is shown in Fig. 1. The reservoir consists of a vertical 2-in. pipe packed with Wilcox sand. A thin coating of sand was shellacked to the wall to prevent channeling. The ends and pressure taps were packed with glass wool to prevent loss of sand. The entire tube was 93.6 ft. long with pressure taps at 18.4-ft. intervals. Pressure taps were brought to ground level by ¼-in. connections, which were filled with heptane.

Gas was brought in through the top of the tube after passing through a silica gel drier. Valves 1 and 2 were used to fill the tube; valve 3 was the controlling valve for the unsteady runs. The outlet stream was measured by a positive meter. Thermocouples were placed at the top, bottom and middle of the tube.

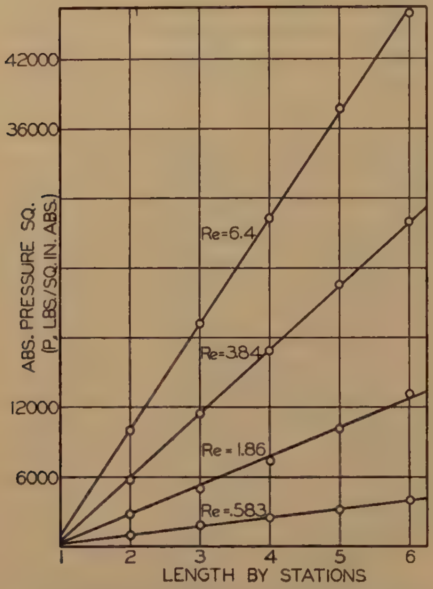

FIG. 2.—STEADY-STATE NATURAL-GAS RUNS. Absolute pressure squared versus length by stations. No. 1 is bottom station. Re = Revnolds Number.

The porosity of the sand used in these experiments was 33 per cent, the permeability 7.2 darcys, measured in situ. The Reynolds number was calculated by the method suggested by Fancher and Lewis.[2] It was found that turbulence set in at a Reynolds number of 1.00 to 2.00.

In order to determine whether the permeability was constant along the length of the tube, steady-state runs were made. The results are given in Fig. 2, which shows that the permeability was approximately constant throughout. The change in dynamical nature of the flow is also indicated.

EXPERIMENTAL PROCEDURE

The actual experimental procedure was as follows: The initial pressure readings due to the head of heptane were recorded. The tube was then filled with dry gas. When less than 0.5 per cent oxygen appeared in the outlet stream, the bottom valve was closed and the tube was filled to the predetermined pressure; the inlet valve was then closed. To start the runs, valve No. 3 was opened, and the instant flow registered on the meter the stop watch was started. Pressure readings were taken at all stations simultaneously—at first every minute; at longer intervals as the flow decreased.

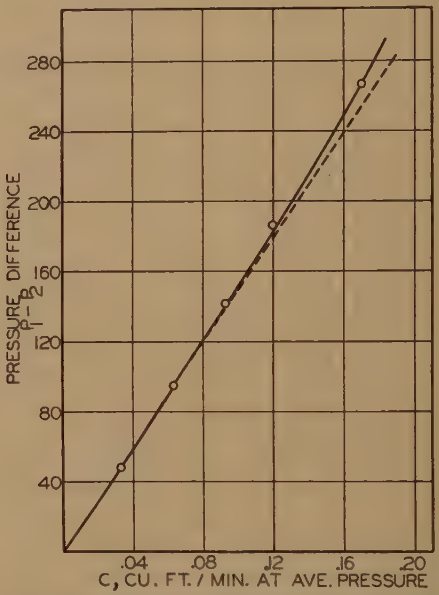

FIG. 3.—PRESSURE DIFFERENCE VERSUS RATE MEASURED AT AVERAGE PRESSURE. STEADY-STATE RUN ON NATURAL GAS.

Over the range of pressures covered by these experiments the deviation of gas from Boyle's law somewhat affected the results. To check this the tube was allowed to produce for certain periods and the outlet valve was then closed, allowing the pressure to equalize. The volume remaining in the tube, as determined by deducting the metered volume from the initial contents, was compared with the average shut-in pressure. As observed, the calculated accumulative production differed from the experimental data more on the CO_2 runs than on the H_2 runs. This is due at least in part to the greater supercompressibility of CO_2 at this temperature and pressure.

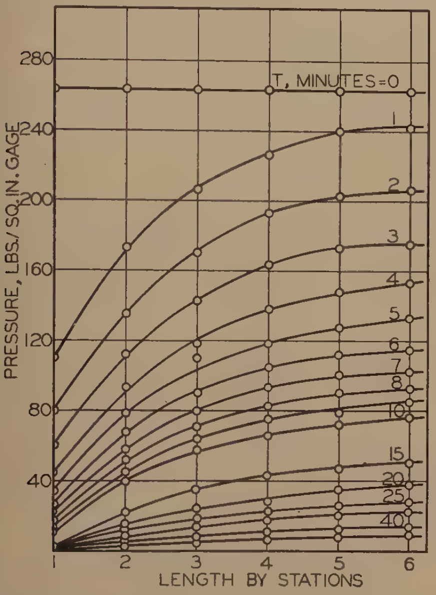

FIG. 4.—PRESSURE CHANGE WITH TUBE LENGTH. UNSTEADY RUN ON NATURAL GAS. NO. 1 IS BOTTOM STATION.

The natural gas used was about 97 per cent methane, with no constituents higher than propane in appreciable quantity. The hydrogen and carbon dioxide were commercial grade.

DISCUSSION OF RESULTS

Results of the experiments are given in Figs. 4 to 18, where the pressure, rate of production and cumulative production are given in relation to the length of the tube and to time. Although appearance is no criterion, the results do not seem markedly different from those derived from the steady-state approximations.

The general results of this experimental work in their relation to any immediate practical application are found in their degree of agreement with Eqs. 2 and 3. Eq. 3 is widely used to determine the open flows and productive capacities of natural-gas wells. The assumptions concerning the steady state described above are implicitly involved in this equation. These experiments, where the flow was most decidedly not in the steady state, check this equation well within the limits of accuracy observed in field applications of the same equation. The agreement with Eq. 2 is not as close; owing in great part to the difficulty in determining the correct value of C_0. Extrapolation of observed rates of flow to zero time may considerably affect the resultant numerical values found from Eq. 2. Even so, the degree of agreement shown appears to be sufficiently close to permit application of the equation in actual field studies.

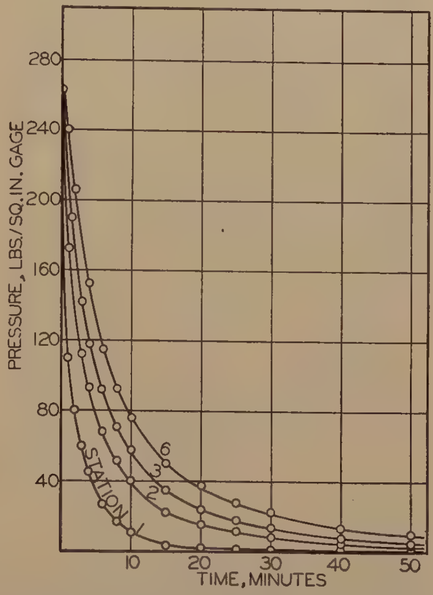

FIG. 5.—PRESSURE CHANGE WITH TIME. UNSTEADY RUN ON NATURAL GAS. NO. 1 IS BOTTOM STATION.

Although no closed reservoir can flow in the steady state, it may follow what

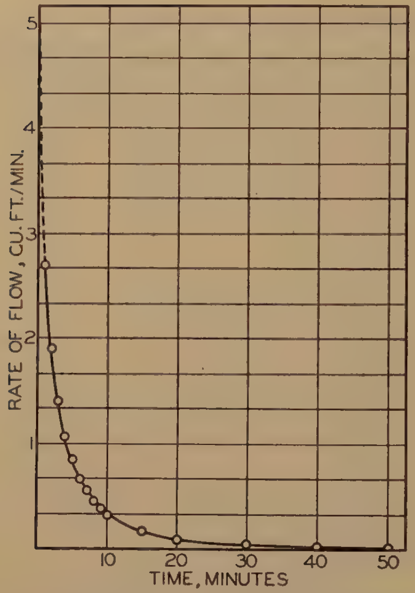

FIG. 6.—PRODUCTION DECLINE WITH TIME, RUN 29. UNSTEADY FLOW OF NATURAL GAS.

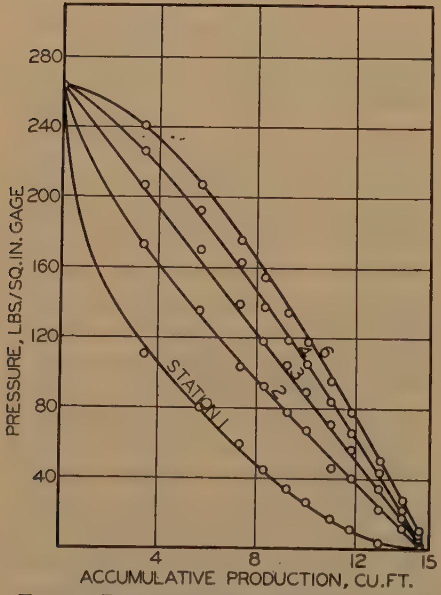

FIG. 7.—PRESSURE DECLINE VERSUS CUMULATIVE PRODUCTION. UNSTEADY FLOW, NATURAL GAS. No. 1 IS BOTTOM STATION.

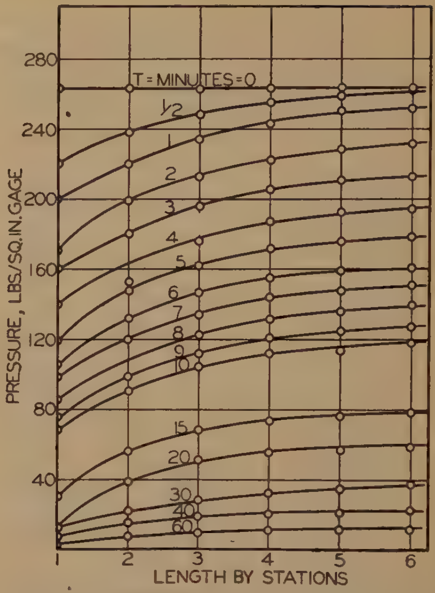

FIG. 8.—PRESSURE CHANGE WITH LENGTH OF TUBE. UNSTEADY FLOW, NATURAL GAS. RUN 30.

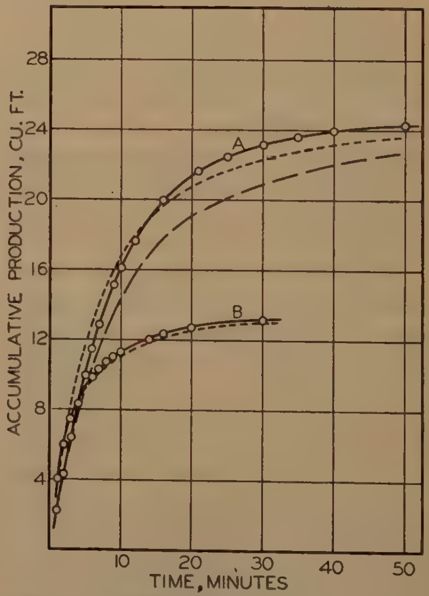

FIG. 9.—CUMULATIVE PRODUCTION VERSUS TIME. *A*, RUN 40; *B*, RUN 41. UNSTEADY FLOW OF HYDROGEN.

Solid line indicates Q, experimental; short dashes, Q calculated by Eq. 2; long dashes, Q calculated by Eq. 4.

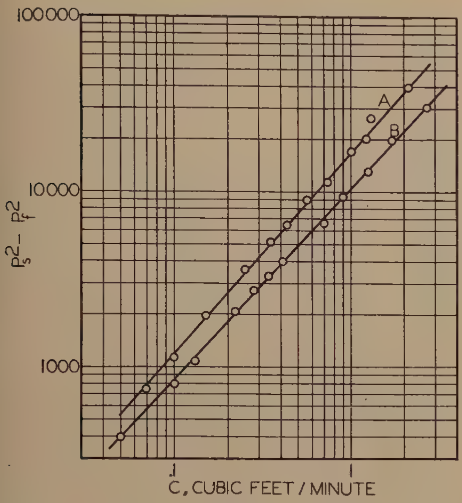

Fig. 10.—Log of difference of squares of shut-in pressure and flowing pressure versus log of rate of production, *A*, run 40; *B*, run 41.
Both runs represent unsteady flow of hydrogen.

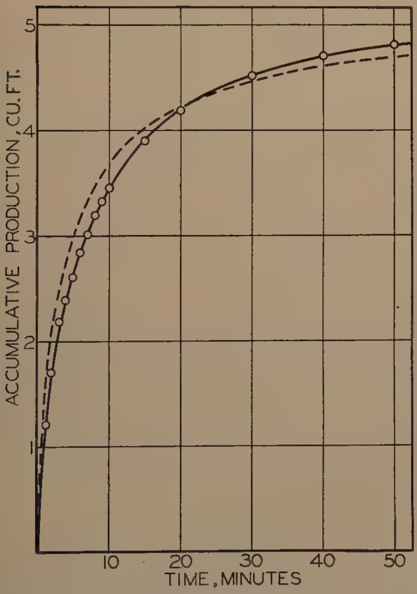

Fig. 11.—Cumulative production versus time, run 32. Unsteady flow of natural gas.

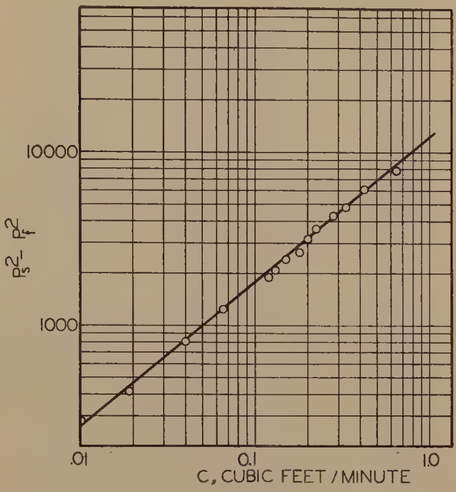

Fig. 12.—Log of difference of squares of shut-in pressure and flowing pressure versus log of rate of production, run 32. Unsteady flow of natural gas.

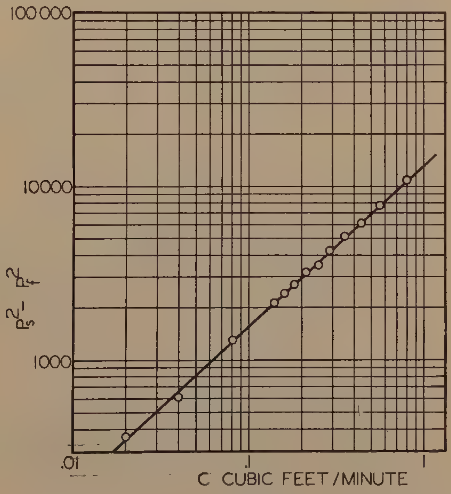

Fig. 13.—Log of difference of squares of shut-in pressure and flowing pressure versus log of rate of production, run 33. Unsteady flow of natural gas.

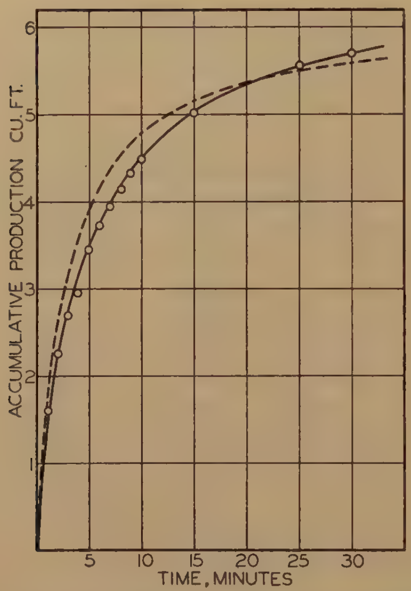

FIG. 14.—CUMULATIVE PRODUCTION VERSUS TIME, RUN 33. UNSTEADY FLOW OF NATURAL GAS.

Solid line, Q experimental; dashed line, Q calculated by Eq. 2.

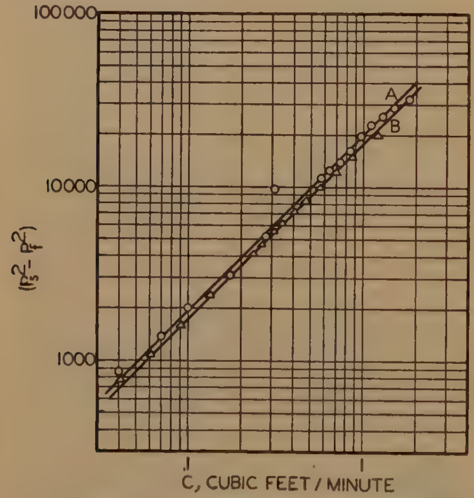

FIG. 15.—LOG OF DIFFERENCE OF SQUARES OF SHUT-IN PRESSURE AND FLOWING PRESSURE VERSUS LOG OF RATE OF PRODUCTION, RUN 36, *A*; RUN 38, *B*. UNSTEADY FLOW OF CARBON DIOXIDE.

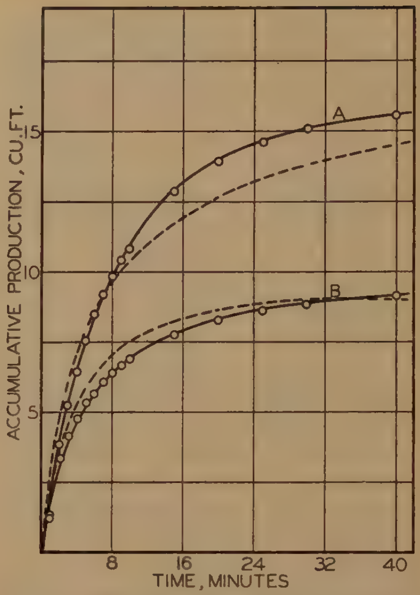

FIG. 16.—CUMULATIVE PRODUCTION VERSUS TIME, *A*, RUN 36; *B*, RUN 38. UNSTEADY FLOW OF CARBON DIOXIDE.

Solid line, Q experimental; dashed line, Q calculated by Eq. 2.

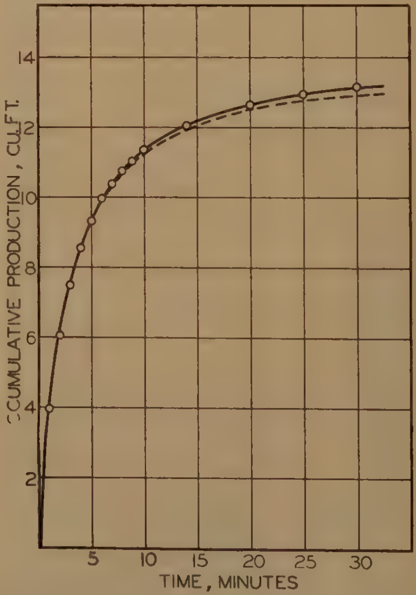

FIG. 17.—CUMULATIVE PRODUCTION VERSUS TIME CALCULATED FROM TIME EQUAL FIVE MINUTES. UNSTEADY FLOW OF HYDROGEN.

Solid line, Q experimental; dashed line, Q calculated by Eq. 2.

may be termed a "steady-state decline"; i.e., where the change in potential with time is independent of the position in the system. Thus there would be an initial period of transient conditions, commonly referred to in field parlance as the "recession of the radius of drainage," followed by a longer period of steady decline. In these experiments it was found that after a certain length of time, about 3 or 4 min., the pressure decline (dp/dt) was independent of the position in the system. The initial few minutes, then, represent the initial transient. It was found that Eq. 2 gave much closer approximations if applied to the period after this initial transient had passed. It would seem, and the conclusion had been previously drawn from field experience, that the principal difficulty in applying the theory of a succession of steady states lies in the initial transient period, which may be of much longer duration than is commonly supposed. The fact that in a linear system of these dimensions the initial transient lasted for 3 min. is possibly indicative of a much longer period in actual gas fields than has been suspected.

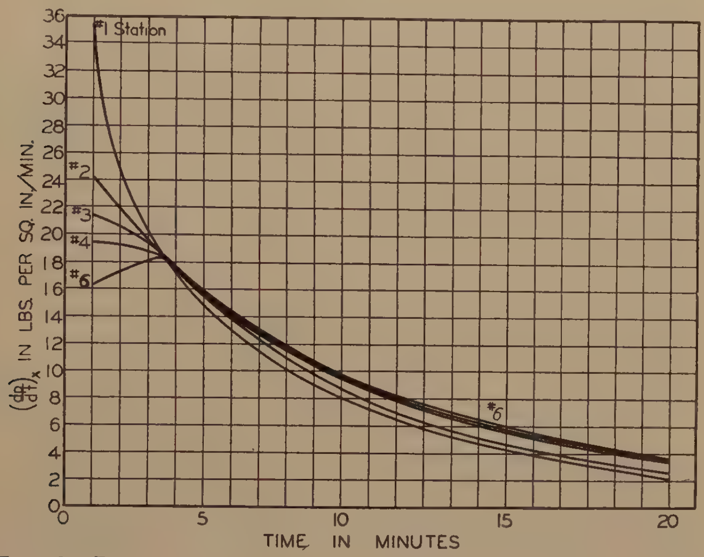

FIG. 18.—PRESSURE GRADIENT VERSUS TIME FOR THE SEVERAL STATIONS.

CONCLUSIONS

The experiments described herein tend to verify the accuracy of the "back-pressure" method of testing gas wells, provided that the period of transient conditions for the reservoir is not of too long a duration. The assumption of successive steady states is further seen to hold with fair validity in calculating future production and rates of decline. Since the experiments are designed to test the general validity of the assumptions, variations in boundary conditions—i.e., manipulations of rates of production—should in no way affect the conclusions drawn. Their effect will be to add complications to the mathematical statements.

Since the general theory of reservoir drainage has already found full application in practice in well testing, calculations of well spacing and evaluation of reserves, a verification of the fundamental assumptions is valuable at this stage. It would appear that further investigation of the period of initial transients is desirable.

ACKNOWLEDGMENTS

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Equations 2 and 4 are taken from unpublished papers on the economics of gas production by D. T. MacRoberts and R. D. Burford, of the United Gas Pipe Line Company.

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Dimensional-model Studies of Oil-field Behavior

By M. C. Leverett,* Junior Member A.I.M.E., W. B. Lewis† and M. E. True*

(Dallas Meeting, October 1941)

This paper states the theory underlying the design of two kinds of dimensionally scaled models of parts of idealized oil fields. One of these simulates an oil well and its surrounding sand for a distance of 16 ft. radially from the well. The other model simulates linear flow through layered sands. Construction and operation of the models are described and typical data are given. The unique features in the design of the models are: (1) the treatment of the permeability-viscosity quotient as a single variable and (2) the use of previously reported experimentally developed relations between relative permeability and saturation and capillary pressure, saturation, porosity, permeability and interfacial tension. The models at present simulate flow of oil and water only, through unconsolidated sands. They are superior to unscaled models, which may give rise to erroneous conclusions. The models are designed to study the desirability of various methods of well completion and the effects of various factors on recovery of oil from layered sands.

Introduction

Recent work on the fundamental behavior of flowing mixtures of fluids in sands has resulted in the development of some new theory in this field, much of which has been presented in previous papers.[1–4] However, the application of this theory to the behavior of oil wells or oil fields has proved too complicated for ordinary mathematical techniques, except in very highly simplified cases. A practical solution to this problem appears, therefore, to lie in the use of dimensionally scaled models of elements of oil fields.

The object of this paper is, first, to present the theoretical and experimental basis of the design of such models, and, second, to describe their construction and operation. Experiments now under way on the models already built will yield material for other reports, which will be devoted to interpretation of the results in terms of oil-field behavior.

So far, simple dimensional models of two kinds have been built and are being operated. These models represent different parts of an idealized oil field but obey the same underlying theory. The only fluids represented are oil and water, since certain questionable approximations are necessary for gas-liquid systems.

General Theory

Dimensional models have been used in other fields for a long time, and their theory is adequately given in the literature.[5] Here, it suffices to state that each physical element entering into a dynamic relation may be given a definite description in terms of three fundamental, but arbitrarily chosen, dimensions. These usually are mass, length, and time, symbolized here by the small letters m, l, and t.

Two systems are said to be dimensionally similar or dimensionally scaled if for each element in one system there is a corresponding element in the second system and the ratios of the numerical magnitudes of corresponding elements are constant for all elements of the same dimensional type.

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† The Elflex Company, Houston, Texas.

[1] References are at the end of the paper.

For example, if in a model there is a scaled element whose numerical value is G', having dimensions $(l)^a(m)^b(t)^c$, the numerical value G of the corresponding element of the prototype may be found from the expression

$$\frac{G}{G'} = \left(\frac{L}{L'}\right)^a \left(\frac{M}{M'}\right)^b \left(\frac{T}{T'}\right)^c \qquad [1]$$

where the ratio L/L' represents the ratio of corresponding elements of length, T/T' of time, and M/M' of mass. Primes are used to denote properties of the model; absence of primes, those of the prototype. The four ratios appearing in Eq. 1 are termed "scale ratios," and these ratios are the ones that must be constant for corresponding elements of model and prototype. Dimensionless properties, such as fractional porosity or functions of angles, are numerically the same in model and prototype.

SELECTION OF VARIABLES TO BE SCALED

The first step in the design of a model is to delimit the system—that is, to select the variables pertinent to the process under study—since these and only these need be scaled. In some cases physical intuition must be relied upon for the selection of these variables but for our tests their selection is easy, since we can write the fundamental differential equation for the mixture flow process, and we can state mathematically the boundary conditions on it for any particular problem. Obviously, all the pertinent variables must appear in these expressions, and all the variables that appear are pertinent, so that it is necessary only to enumerate these quantities to determine what properties of the prototype need be scaled in the model.

The fundamental differential equation can be derived in two steps. First, the equation of continuity is derived, and is readily shown to be

$$\frac{\partial}{\partial x}(q_{tx}f_x) + \frac{\partial}{\partial y}(q_{ty}f_y) + \frac{\partial}{\partial z}(q_{tz}f_z) = -\phi\frac{\partial S}{\partial \theta} \qquad [2]$$

Second, recourse is had to a previously derived[4] expression for f, which is

$$f_u = \frac{1 + \dfrac{K_o}{q_{tu}\mu_o}\left[\dfrac{\partial P_c}{\partial u} - g\Delta\rho\cos\alpha\right]}{1 + \dfrac{K_o}{K_w}\dfrac{\mu_w}{\mu_o}} \qquad [3]$$

The meanings of the symbols are given in Table 1. This expression is differentiated with respect to each of the three principal directions x, y and z, and the derivatives are substituted in Eq. 2. The result is the fundamental differential equation sought. Since only the quantities in Eqs. 2 and 3, or their space derivatives, appear in this equation, it is unnecessary explicitly to present it here.

TABLE 1.—*Nomenclature and Dimensions of Variables*

Symbol	Meaning	Dimensional Description
B_o*	Effective fluid conductivity to oil; $B_o = K_o/\mu_o$	l^3t/m
B_w*	Effective fluid conductivity to water; $B_w = K_w/\mu_w$	l^3t/m
f*	Fraction of flowing stream comprising water	None
g*	Gravitational constant	l/t^2
$j(S)$*	Capillary pressure function	None
K_o	Effective permeability to oil	l^2
K_w	Effective permeability to water	l^2
$k_o(S)$*	Relative permeability to oil; $k_o(S) = K_o/K$	None
$k_w(S)$*	Relative permeability to water; $k_w(S) = K_w/K$	None
K	Specific permeability of sand	l^2
P_c*	Capillary pressure; P_c = pressure in oil − pressure in water	m/lt^2
ΔP*	Pressure differential	m/lt^2
Q_t*	Total production rate (example: bbl. per day)	l^3/t
q_t*	Linear flow rate (example: bbl. per sq. ft. of cross section per day)	l/t
S*	Fractional water saturation	None
u*	Distance in any direction, u	l
x, y, z*	Usual rectangular space coordinates; used to state size and shape of system	l
α*	Angle of inclination of direction u with horizontal	None
γ	Interfacial tension between liquids	m/t^2
θ*	Time	t
μ_o	Viscosity of oil phase	m/lt
μ_w	Viscosity of water phase	m/lt
$\Delta\rho$*	Difference in densities of oil and water	m/l^3
ϕ*	Fractional porosity	None

* Pertinent properties of system. Must be scaled.

The boundary conditions on this equation consist of the linear measurements of the sand body to be studied, including the parts of the well equipment that actually touch the face of the sand, and the initial distribution of pressure gradients and liquid saturation in it.

Eqs. 2 and 3 show that the effective permeabilities and liquid viscosities always appear as the quotients K_o/μ_o and K_w/μ_w. These quotients, therefore, may be regarded as single variables, called B_o and B_w, respectively, the "effective fluid conductivities." These new variables, rather than the effective permeabilities or viscosities alone, are the ones pertinent to the process and therefore are the ones to be scaled.

It is to be remarked that although Eqs. 2 and 3 do not contain explicitly the pressure gradient, this is because it has been made to cancel out of Eq. 3. Because of this the scaling procedure adopted here implicitly scales the pressure gradient. However, the total pressure is not a pertinent variable except insofar as it may affect viscosity, interfacial tension, density, or other properties in the prototype. The fact that these properties are themselves scaled in the model permits the carrying out of the experiments at any convenient total pressure without in any way invalidating the results.

Arbitrary Fixing of Model Properties

In designing the model certain of its properties may be fixed arbitrarily. However, the rules of dimensional analysis state that only as many dimensionally independent properties as there are fundamental dimensions may be fixed—in this case, three. Once three such properties have been fixed the values of the fundamental scale ratios L/L', M/M', and T/T' and those of all other scaled properties of the model also are fixed.

In the present case, the equations show that g, the gravitational constant, is one of the pertinent variables. But g cannot be altered conveniently, hence must be regarded as having been arbitrarily fixed, leaving only two other properties of the model that may be established independently.

Further, the fact that the model is to be smaller than the prototype by a definite ratio fixes the linear measurements of the model and hence the fundamental scale ratio L/L'. This also fixes the value of the ratio T/T', because g/g' is unity, and with both length and time scales thus specified the ratio q_t/q_t' also is fixed.

Four pertinent variables remain as yet unspecified. These are B_o, B_w, P_c, and $\Delta\rho$, of which only one may be fixed at will. But on examining the suitable pairs of liquids available for use in the models we find that their density differences are very nearly those of the liquids in the prototype we wish to scale, so that the scale ratio $\Delta\rho/\Delta\rho'$ is very nearly equal to unity. Establishing this ratio fixes also the ratio M/M', and thus indirectly determines the ratios B_o/B_o', B_w/B_w', and P_c/P_c'. This means that the sands and liquids used in the model must be so chosen that these ratios have their proper values. This choice is made easier by two correlations, which have been developed experimentally. These relationships will be discussed in some detail in the succeeding paragraphs.

Use of Experimental Correlations in Scaling B_o, B_w, and P_c

Previously reported studies on simultaneous flow of mixtures of fluids through sands[1,2] show that K_o and K_w, the effective permeabilities to oil and to water, are proportional to the specific permeability of the sand, but for a given sand vary with the water saturation. Recalling the definitions of B_o and B_w, we may therefore write as good approximations

$$B_o = \frac{Kk_o(S)}{\mu_o} \qquad [4a]$$

$$B_w = \frac{K\,k_w(S)}{\mu_w} \qquad [4b]$$

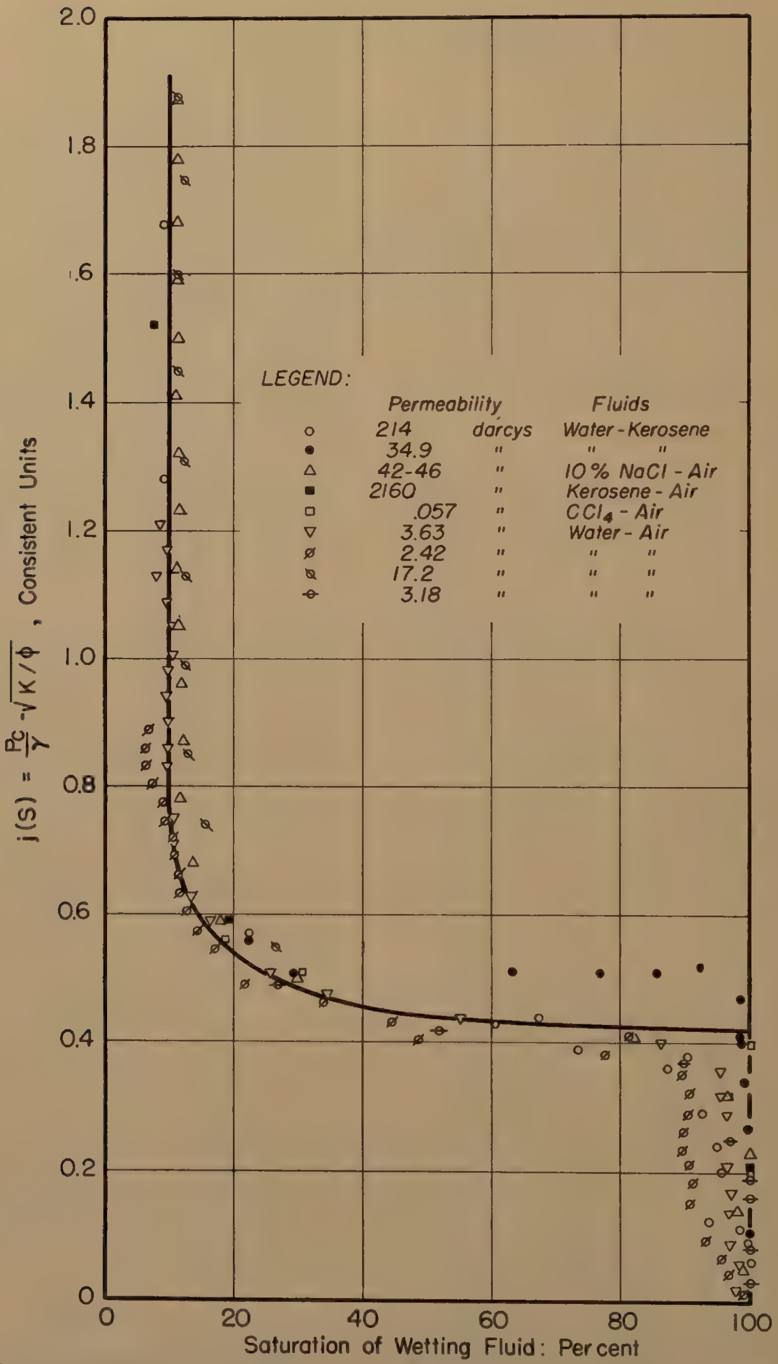


FIG. 1.—RETENTION OF CAPILLARY LIQUID IN UNCONSOLIDATED GRANULAR SOLIDS.

where $k_o(S)$ and $k_w(S)$ are the relative permeabilities to oil and to water, dimensionless functions principally of water saturation. For most clean unconsolidated sands the relative permeabilities are substantially independent of the properties of the sands or fluids. Consolidated sands, however, do not obey this rule, different sands giving rise to different relative permeability functions.

Eqs. 4 may be regarded as statements of the relative permeability-saturation relation. This relationship is one of the two experimental correlations that will be used.

The second correlation states that the capillary pressure P_c is proportional to the interfacial tension γ, to the radical $\sqrt{\phi/K}$, and to a dimensionless function of the water saturation $j(S)$:

$$P_c = \gamma j(S) \sqrt{\phi/K} \qquad [5]$$

This relationship was reported[4] to hold for static equilibrium, and recent experiments, on a wider variety of solids, have confirmed this conclusion. In both sets of experiments it was found, however, that the function $j(S)$ is not single-valued, but depends in part on the history of the system. Apparently also it depends to some extent on whether the fluids are flowing or static, but the available data support the conclusion that Eq. 5 is valid for a given history and state of motion of the system.

Fig. 1 shows the data that suggest that Eq. 5 is valid under static conditions for a variety of solids inert to the fluids used. These data were obtained by letting the liquids drain to capillary-gravitational equilibrium in vertical columns. The validity of Eq. 5 has been investigated under dynamic conditions also. In this investigation measurements were made of the rates at which various liquids are imbibed horizontally by various grades of sand. The rate of imbibition at a given saturation should theoretically be proportional to the capillary pressure P_c and to a complex function of the effective fluid conductivities. However, where the viscosity of the nonwetting phase is small, as with air, this function reduces to the effective fluid conductivity for the imbibing liquid. Eqs. 4 and 5 show that the rate of liquid imbibition into a sand partially filled with air should be proportional to the group $P_c \times B = \left(\frac{\gamma}{\mu}\sqrt{K\phi}\right) \times$ (function of saturation). Fig. 2 shows the data from these experiments. The liquids used were kerosene, carbon tetrachloride, water, and a mixture of kerosene and lubricating oil, while the sands ranged from one of which 50 per cent passed a 325-mesh screen to a 20 to 30-mesh size. The sands were saturated initially to about 11 per cent with the liquid to be used. As predicted by theory, the data all fall along a straight line through the origin. A 10 to 20-mesh sand proved too coarse to follow this rule, but the 20 to 30-mesh sands used in the present model studies obeyed it satisfactorily.

It should be emphasized that these correlations are valid only for clean sands; the presence of hydratable material in the sands has a large effect on the several dimensionless functions of saturation mentioned above.

In order to use Eqs. 4*a*, 4*b* and 5, it is necessary to recall that model and prototype go through the same saturation history, and that the various dimensionless functions of saturation therefore are numerically the same at the same relative time. From this it follows that

$$\frac{B_o}{B_o'} = \frac{K}{K'}\frac{\mu_o'}{\mu_o} \qquad [6]$$

$$\frac{B_w}{B_w'} = \frac{K}{K'}\frac{\mu_w'}{\mu_w} \qquad [7]$$

$$\frac{P_c}{P_c'} = \frac{\gamma}{\gamma'}\sqrt{\frac{K'}{K}} \qquad [8]$$

Thus, if a given value of B_o/B_o' is required, it may be obtained by selecting at will a sand of convenient permeability and an oil having the viscosity required by Eq. 6. Or a pair of liquids having a particular interfacial tension and a sand having the permeability required by Eq. 8 may be used. Although the values of B_o', B_w' and P_c' are fixed by the scale ratios chosen, these values may be obtained by a large number of combinations of sand and fluids. This additional flexibility is important, because without it a useful model could not be designed.

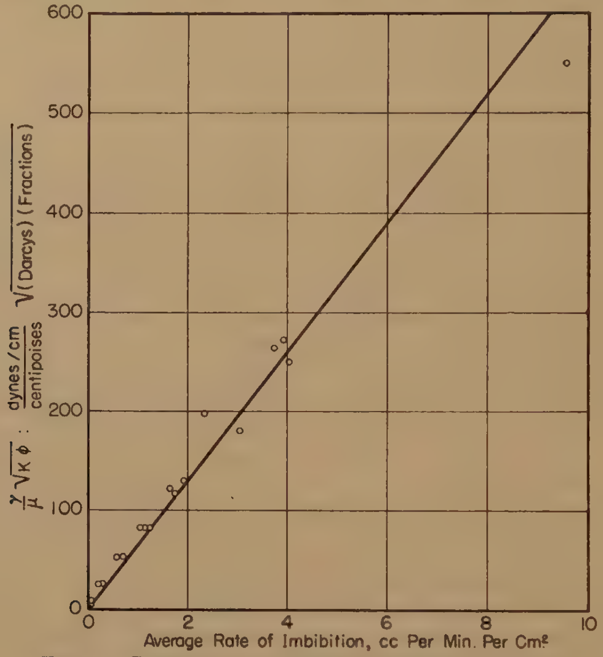


FIG. 2.—CORRELATION OF IMBIBITION RATES IN SANDS.

It is interesting to observe that, because the foregoing reasoning may be inverted, a given model corresponds to a very large number of prototypes. However, a particular model does not correspond to all prototypes.

COMPUTATION OF SCALE RATIOS

The foregoing equations and the information in Table 1 make possible the computation of any desired scale ratio, but it is convenient to have the proper relationships stated explicitly. Usually the value of the fundamental ratio L/L' and the values of the ordinary properties of the sands and liquids are known. The scale ratios, therefore, should be expressed in terms of these quantities.

The fundamental ratio T/T' is given in terms of L/L' by the equation:

$$\frac{T}{T'} = \sqrt{\frac{L}{L'}} \qquad [9]$$

This equation is a consequence of the fact that g/g' is unity. The fundamental ratio M/M' is given by the equation:

$$\frac{M}{M'} = \left(\frac{\Delta\rho}{\Delta\rho'}\right)\left(\frac{L}{L'}\right)^3 \qquad [10]$$

This equation follows from the dimensional description of density.

Other scale ratios are tabulated in Table 2. These latter expressions are derived from the data of Table 1 and Eqs. 9 and 10 by simple algebraic manipulation. They are the expressions actually used to design a model of a given prototype or to determine the properties of the prototypes to which a given model corresponds.

CHOICE OF MATERIALS FOR MODELS

Table 2 shows that the liquids to be used in the model must be much more viscous than those in the prototype in order to satisfy the dimensional analysis, so that ordinary crude oils and brines are not suitable. However, the aqueous phase used in the model must have the same wetting affinity for the sand as the brines found in nature, and the liquid used to represent oil must not preferentially wet the sand. Further, Table 2 shows that very permeable sands also must be used in the models.

TABLE 2.—*Expressions for Computing Scale Ratios*

Ratio	Value in Terms of Length-scale Ratio and Ordinary Properties of Sand and Liquids	Typical Value for 16-scale Model[a]
B_o/B_o' or B_w/B_w'	$\left(\frac{\Delta\rho'}{\Delta\rho}\right)\left(\frac{L}{L'}\right)^{1/2}$	4
g/g'	1	1
K/K'	$\left(\frac{\mu}{\mu'}\right)\left(\frac{\Delta\rho'}{\Delta\rho}\right)\left(\frac{L}{L'}\right)^{1/2}$	
	$=\left(\frac{\gamma}{\gamma'}\right)^2\left(\frac{\Delta\rho'}{\Delta\rho}\right)^2\left(\frac{L'}{L}\right)^2$	1/64
P_c/P_c' or $\Delta P/\Delta P'$	$\left(\frac{\Delta\rho}{\Delta\rho'}\right)\left(\frac{L}{L'}\right)$	16
Q_t/Q_t'	$\left(\frac{L}{L'}\right)^{5/2}$	1024
q_t/q_t'	$\left(\frac{L}{L'}\right)^{1/2}$	4
$u/u' = x/x' = y/y' = z/z'$	$\left(\frac{L}{L'}\right)$	16
γ/γ'	$\left(\frac{K}{K'}\right)^{1/2}\left(\frac{\Delta\rho}{\Delta\rho'}\right)\left(\frac{L}{L'}\right)$	
	$=\left(\frac{\Delta\rho}{\Delta\rho'}\right)^{1/2}\left(\frac{L}{L'}\right)^{5/4}\left(\frac{\mu}{\mu'}\right)^{1/2}$	2
θ/θ'	$\left(\frac{L}{L'}\right)^{1/2}$	4
μ_o/μ_o' or μ_w/μ_w'	$\left(\frac{K}{K'}\right)\left(\frac{\Delta\rho}{\Delta\rho'}\right)\left(\frac{L'}{L}\right)^{1/2}$	
	$=\left(\frac{\gamma}{\gamma'}\right)^2\left(\frac{\Delta\rho'}{\Delta\rho}\right)\left(\frac{L'}{L}\right)^{5/2}$	1/256
$\Delta\rho/\Delta\rho'$	$\left(\frac{M}{M'}\right)\left(\frac{L'}{L}\right)^3$	1

Other quantities are dimensionless and have same values in prototype as in model. These are: f, $j(S)$, $k_o(S)$, $k_w(S)$, S, α, ϕ.

[a] This column shows typical values of the ratios in column 1, assuming that the length scale ratio is 16:1, that the interfacial tension in the model is half that in the prototype, and that the density difference between the fluids is the same in model and prototype.

The pairs of liquids having suitable wetting characteristics for use in the present models are fairly closely limited to hydrocarbon oils and water solutions of a few organic compounds, such as alcohols and sugars. The liquids actually used in these studies are a heavy lubricating oil, simulating the crude oil, and glycerine, simulating the water. The sands used are all fine enough to pass a 20-mesh Tyler-scale screen and are previously washed, dried and ignited to insure preferential wetting by glycerin.

LIMITATIONS OF MODEL TECHNIQUE

The scaling procedure employed has several limitations. One fundamental limitation arises from the fact that while the macroscopic linear measurements of the system under study are being reduced by compression to laboratory size, the linear measurements of the microscopic parts of the system are simultaneously being increased by use of coarser sands. Evidently, when the microscopic measurements of the model approach the macroscopic measurements the scaling procedure is no longer valid. This fact limits both the coarseness of the sand that may be used and the smallness of the model that may be studied.

Actually there is a second more important limitation on the coarseness of the sand; that is, the fact that the relative permeability-saturation relationship breaks down for very coarse sands. This breakdown is evidenced by residual oil saturations after water-flooding, which are sometimes as low as 3 per cent in coarse sands, instead of the 9 to 14 per cent normally found in fine sands. The work so far completed suggests that sands retained on a 20-mesh screen are probably near the permissible maximum coarseness; such sands usually have permeabilities of 250 to 300 darcys, depending on their porosity. The fact that the coarseness of the sand may not exceed a certain maximum size limits the extent to which a given system may be scaled down. This implies that scale models of large natural features such as whole oil fields cannot be built, since the models themselves would be impractically large. Parts of oil fields having linear measurements of 50 to 100 ft. are easily amenable to scaling, however. The maximum usable value of the ratio L/L' is probably about 20/1. Theoretically, there is also a minimum sand-grain size, but it is unlikely that such extremely fine powders ever will be considered for use in the present models.

Finally, the scaling technique is limited at present to models using unconsolidated sands containing no hydratable materials. The models may be regarded as representing parts of an idealized oil field, which might conceivably be approached in nature. This is a necessary simplification for the present.

Experimental Equipment

One of the two sorts of models that have been built represents a well plus the producing sands around it for a distance of 16 ft. In this region the flow lines converge on the well radially. The radial model has so far been packed with a homogeneous sand only. The other type of model represents an element of the formation so far removed from the well that flow through it can be considered to be substantially linear. In this linear model, sands of different textures are packed side by side to simulate the layered sands found in nature.

In the radial model the object is to find out how much water is produced with the oil under various conditions of flow rate, well completion, and oil-zone thickness, and to determine approximately how the liquids are distributed in the sand around the well during flow. In the linear model, we are concerned more with oil recovery as a function of the numerous variables that may influence the amount of oil recovered by water displacement.

Construction of Radial Model

The radial model consists of a steel cylinder inside of which is a brass cylinder having perforated sides. The latter holds the sand, screen preventing loss of sand through the perforated sides. The ends of the outer cylinder, which is 24 in. long and 24 in. inside diameter, are closed by circular steel plates. One of these plates forms the top of the inner cylinder, while a movable false bottom, held in place by compaction screws, prevents shifting or loss of sand or entrance of liquid at the bottom of the sand mass. The inner cylinder is slightly smaller than the outer one, and the annulus between the two serves to distribute both liquids uniformly around the circumference of the sand. The well itself is represented by a length of $\frac{3}{8}$-in. brass tubing longitudinally slotted over a part of its length near the middle. The slots represent screen or perforated liner in an oil well. The brass tube extends completely through the center of the sand mass and can be moved vertically so as to place the perforated section at any desired elevation in the sand. The whole apparatus is supported on trunnions, so that it may be inverted for convenience in filling with sand. The maximum working pressure for which the apparatus is designed is 100 lb. per sq. inch.

The liquid supply system consists of a 15-gal. reservoir containing both lubricating oil and glycerine, and two Manzel positive-displacement chemical feeder pumps. One pump transfers oil from the upper part of the reservoir to the top of the annulus outside the sand, while the other takes glycerine from the bottom of the reservoir and discharges it into the bottom of the annulus. The liquids then flow in a generally radial manner through the sand to the well and either are returned to the reservoir to be recirculated or are caught in graduates for rate and composition measurements.

The oil-glycerine contact level in the annulus is also the noncapillary glycerine level in the sand. In order to keep this level constant while the fluids are flowing, a gauge glass is connected to the side of the steel cylinder, and a photoelectric control actuated by changes in level in the glass operates a relay, which, when the glycerine level changes from the desired position, turns off whichever pump is running and simultaneously turns on the other pump. Since both pumps are set to deliver their respective liquids at the same rate, this arrangement assures constant total liquid production rate, and keeps the liquid contact level constant within about 1⁄16 inch.

To obtain some idea of the distribution of liquids in the sand, electrical probes are provided, which can be forced downward into the sand from outside the apparatus. There are 17 of these probes, made of stiff 3⁄32-in. brass rod and spaced at various distances from the well. When the sharpened tip of a probe enters a region in which the glycerine saturation exceeds approximately 70 per cent, an increased current flows in an electrical circuit composed in part of the probe and the sand plus its contained fluids. This increase in current occurs because the glycerine is a better electrical conductor than oil, and its effect is read on the output meter of an amplifier.

Figs. 3 and 4 show the radial model and its accessories.

EXPERIMENTAL PROCEDURE ON RADIAL MODEL

Only one of many possible types of experiments has been performed on the radial model, but a brief description of the procedure used so far will illustrate what can be done.

The apparatus was filled with a weighed amount of previously washed and dried 20 to 30-mesh filtering sand, and the porosity of the sand calculated. A portion of the same sand was packed separately to the same porosity and its permeability was determined. The sand in the model was then saturated with glycerine by alternate evacuation and purging with carbon dioxide, followed by pumping of glycerine through the sand until no undissolved gas remained. The glycerine in the upper part of the sand was then partly displaced with S.A.E. 70 lubricating oil and the photocontrol set to keep the free glycerine level at about 8 in. above the bottom of the apparatus. The perforated section of the tubing representing the well was set slightly above the free glycerine level, and flow at constant rate was commenced. The height of the glycerine zone in the sand was measured periodically with the probes and flow was continued until this height, the composition of the discharge and the pressure drop through the sand attained steady values. The rate of flow, percentage glycerine in the discharge, profile of the glycerine zone and setting of the perforated section of the well were then recorded. Other rates and other perforation settings were then used, the experiment being continued in each case until the attainment of a steady state.

Figs. 5 and 6 show typical data from such runs. The properties of the model studied and of the corresponding prototype are listed in Table 3. The scale ratios were so chosen that one foot in the model represented 16 ft. in the prototype, and the events that take place in one hour in the model would require four hours in the prototype. Table 4 summarizes other data from this same series of runs. Columns 3 and 4 give the vertical distances from the free glycerine level to the top of the region of high glycerine saturation. This is approximately the height of the so-called "water cone" beneath and around the well.

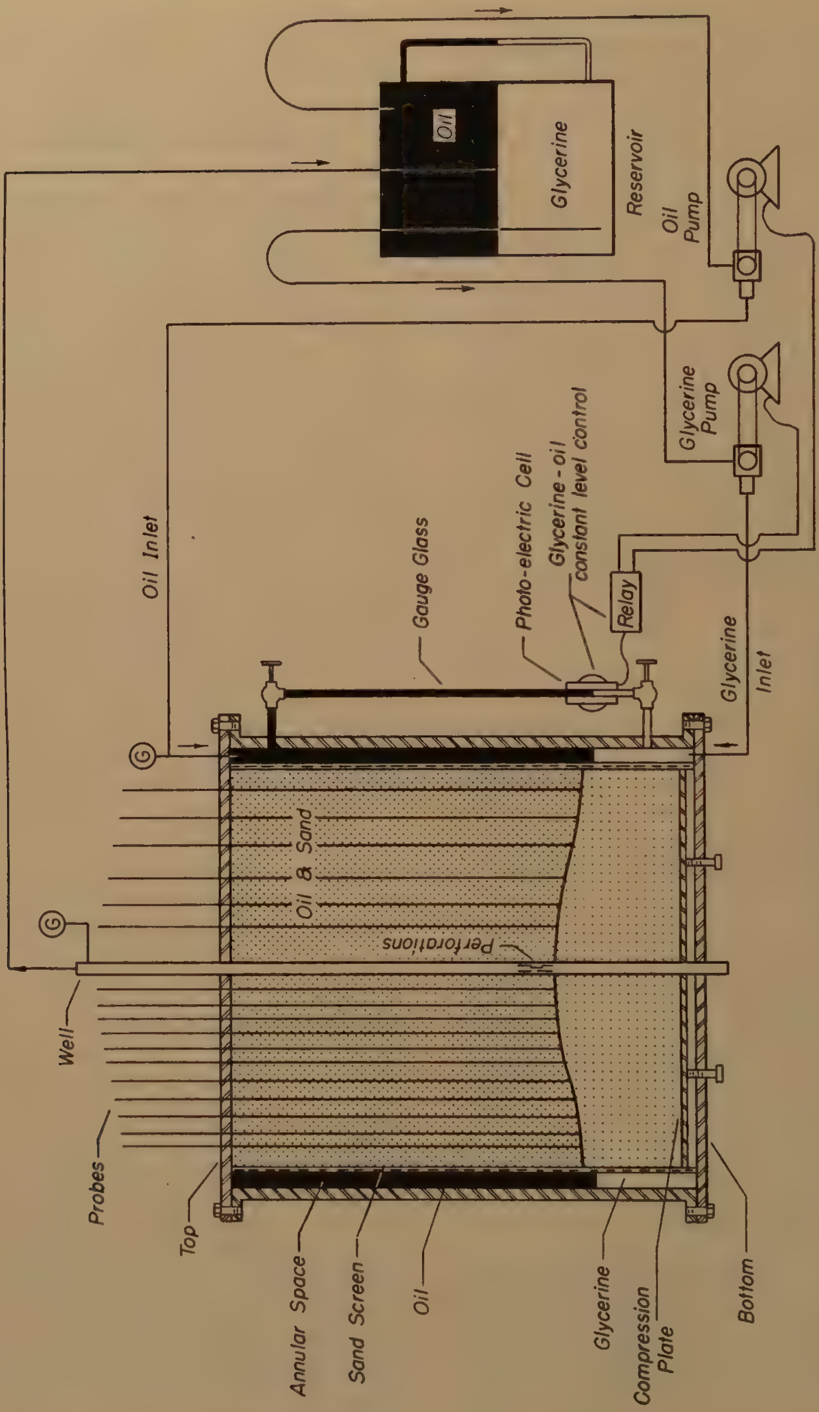


FIG. 3.—DIMENSIONAL MODEL OF AN OIL WELL.

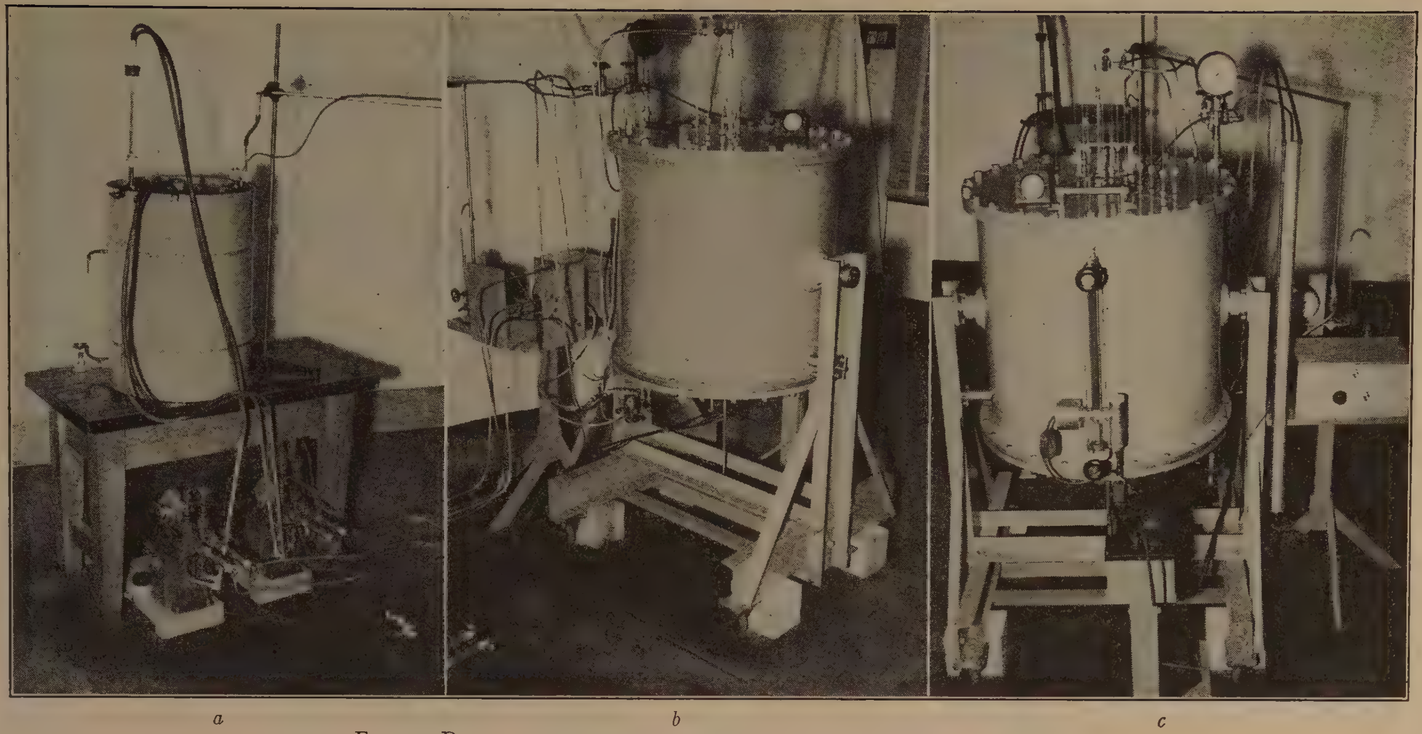


FIG. 4.— DIMENSIONAL MODEL OF AN OIL WELL AND AUXILIARY EQUIPMENT.
a. Fluid-supply tank and pumps.
b. Rear view.
c. Front view.

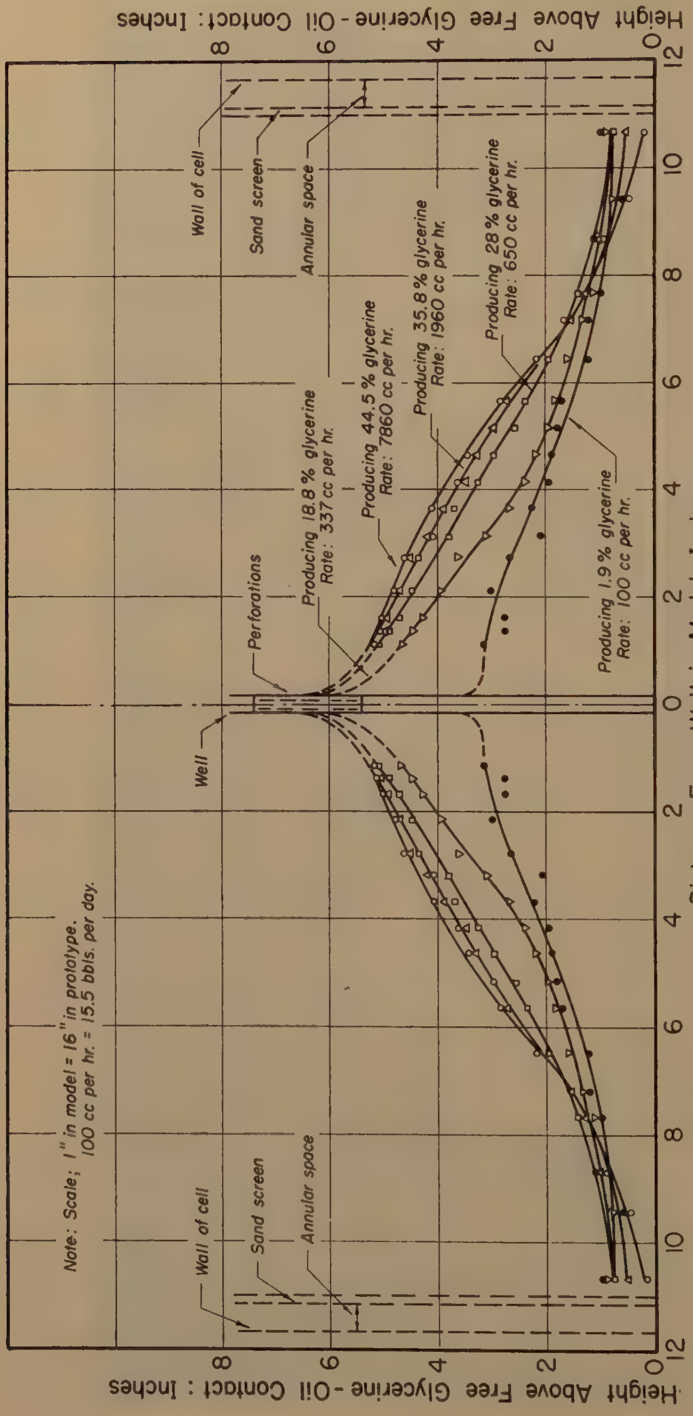


FIG. 5.—CONING IN DIMENSIONAL MODEL OF OIL WELL AT VARIOUS RATES OF PRODUCTION.

CONSTRUCTION OF LINEAR MODEL

The linear model is essentially an aluminum box, 48 by 4 by 1 in. inside dimensions, with provisions made for admitting fluids at one end and discharging them at the other. The box is filled with sands of two sizes, typically arranged as shown in the diagrams of Fig. 7. The model is designed to study experimentally the effects of displacement rate, sand texture, liquid viscosities, sand-body shape and size, direction of displacement, density difference between the liquids, and interfacial tension on the recovery of oil from the sands by water displacement.

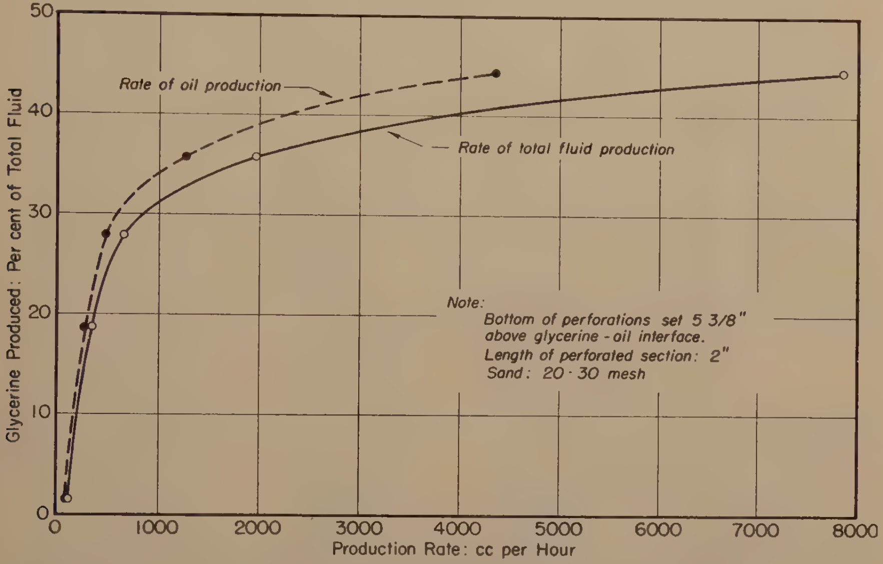


FIG. 6.—EFFECT OF PRODUCTION RATE ON GLYCERIN PRODUCTION FROM DIMENSIONAL MODEL OF OIL WELL.

TABLE 3.—*Properties of Sand and Fluids Studied in Radial Model*

	Laboratory Model	Prototype
Liquid representing oil phase	S.A.E. 70 lubricating oil	Crude oil
Liquid representing water phase	Glycerin	Salt water
Difference in density of fluids, grams per c.c.	0.366	0.366
Oil viscosity, cp.	795	1.99
Viscosity of aqueous phase, cp.	454	1.13
Interfacial tension, dynes per cm.	19.1	30.6
Thickness of sand	24 in.	32 ft.
Diameter of system	22 in.	29.3 ft.
Diameter of well	⅜ in.	6 in.
Sand porosity, per cent	34.5	34.5
Sand permeability, darcys	96	0.96
Rate of flow	100 c.c. per hr.	15.5 bbl. per day

TABLE 4.—*Typical Conditions at Steady-state Equilibrium*

Rate of Production, Total Fluid		Height of Water Cone		Water in Discharge, Model or Prototype, Per Cent
Model, C.c. per Hr.	Prototype, Bbl. per Day	Model, 1 In. from Well, In.	Prototype, 1 Ft. 4 In. from Well, Ft.	
100	15	3⅛	4.2	1.9
337	51	4⅝	6.2	18.8
650	98	$5\frac{1}{16}$	6.8	28.0
1960	294	$5\frac{3}{16}$	6.9	35.8
7860	1180	$5\frac{3}{16}$	6.9	44.5

One side of the apparatus is removable, permitting sampling of the sand and its liquid contents at numerous points. Liquids

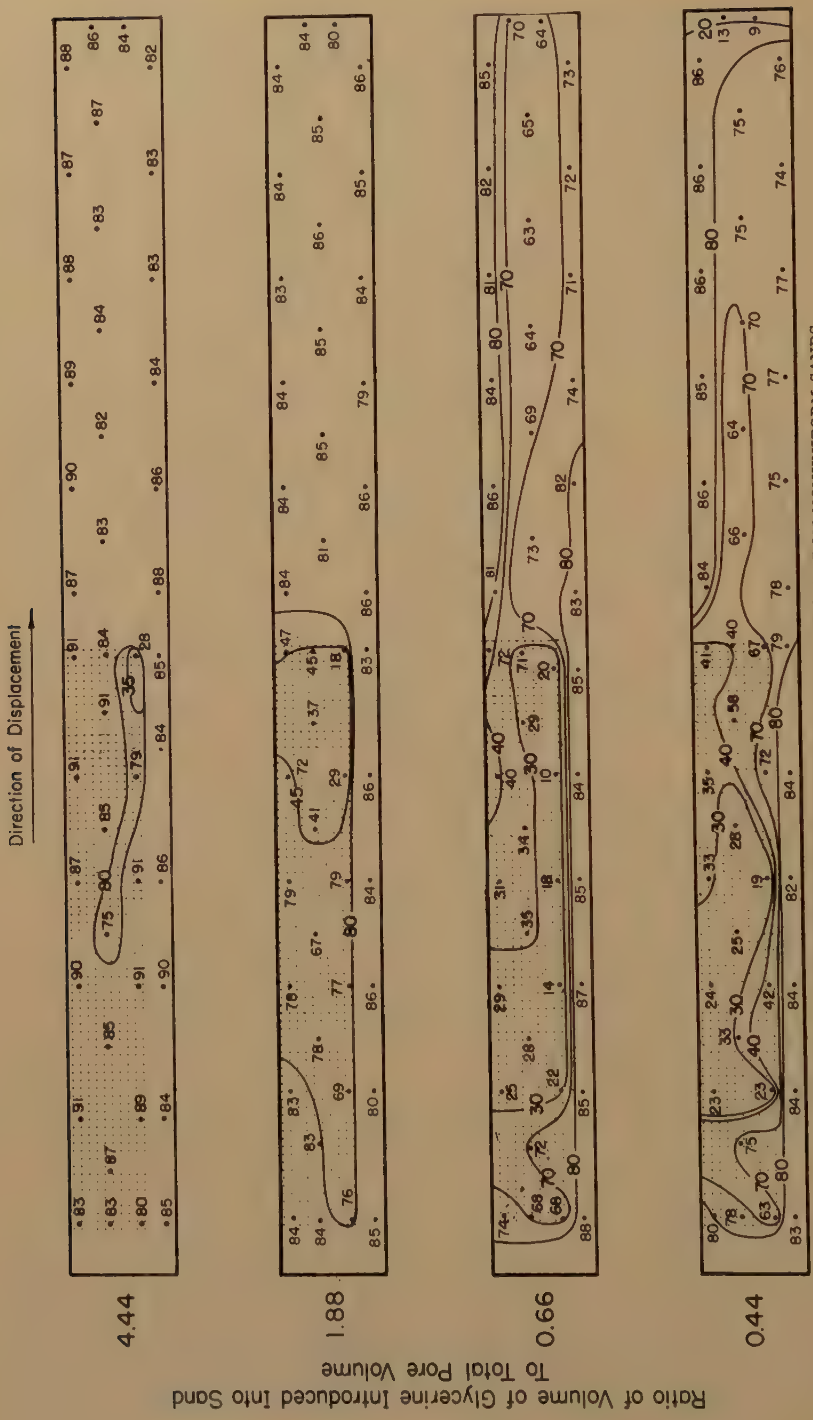


FIG. 7.—FLUID SATURATIONS DURING FLOODING OF OIL FROM NONUNIFORM SANDS. Contours show lines of equal glycerine saturation.

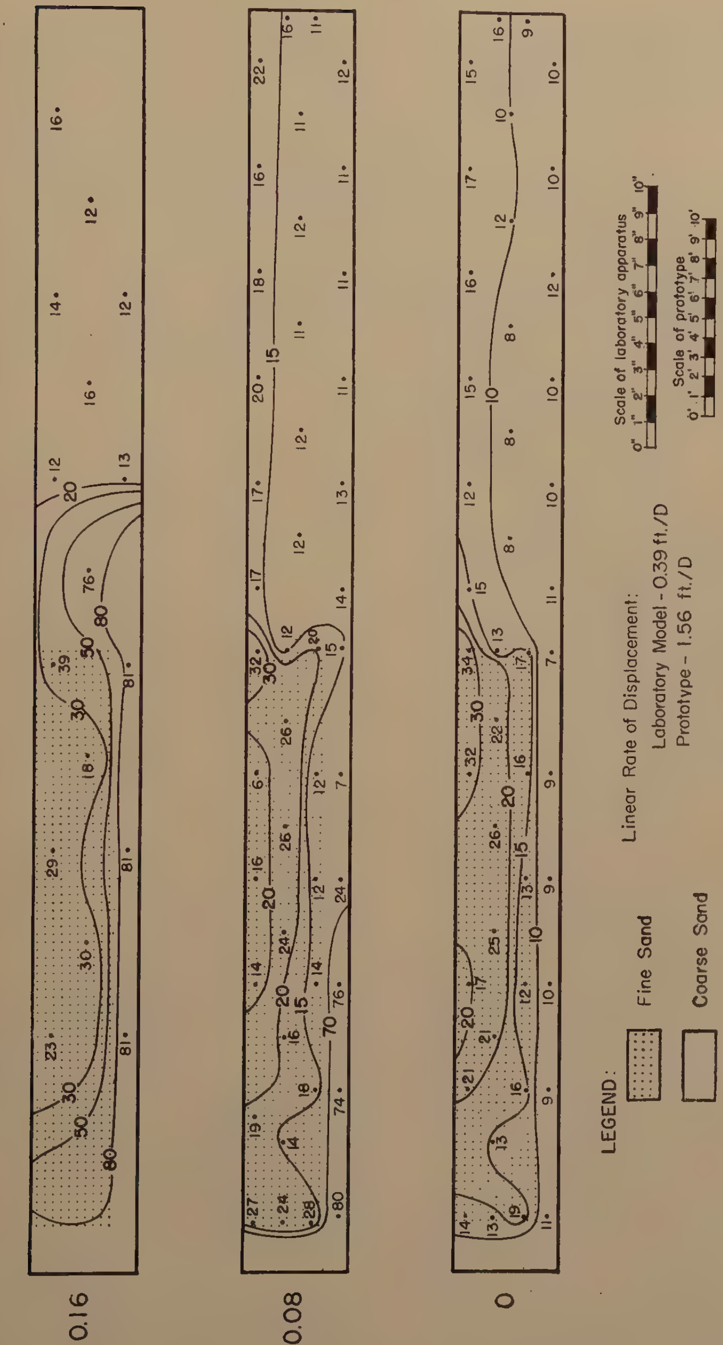


FIG. 7.—(*Continued.*)

are supplied to the apparatus by a Manzel chemical pump. Motion of the sand after packing is prevented by keeping it under compression with a compaction plate and screws.

Experimental Procedure on Linear Model

A typical experiment comprises, first, filling the apparatus with the two sands to be studied. These are previously washed, ignited and screened, and are kept from mixing in the model by a thin metal strip, which is removed after all the rectangular sand lens has been placed. Permeabilities of separate samples of the sands are measured in auxiliary experiments.

Next, the apparatus is purged with carbon dioxide, followed by saturation with glycerine. Oil is pumped through, displacing glycerine, until a predetermined average glycerine saturation has been reached. The removable side of the apparatus is then removed and samples of the two sands are taken from 44 selected locations and analyzed for oil and glycerine.

The analytical procedure comprises adding a measured volume of benzene to the weighed sample, thus extracting the oil from it, and evaporating an aliquot portion of the extract until no benzene remains. The oil residue is weighed. The sand is washed free of glycerine with alcohol followed by ether, dried and weighed. It was found that addition of a small volume of water with the benzene facilitated the extraction step. The oil content can be determined by this technique within about 2 per cent of the amount of oil present, with corresponding accuracy in the glycerine determination. In this way the initial saturation distribution is arrived at. The lowest diagram of Fig. 7 shows a typical initial distribution.

The entire apparatus is then cleaned and recharged with amounts of the two sands, oil and glycerine identical with those used before. After the oil is charged in this time, the sand is flooded out with a definite amount of glycerine at a fixed rate. The apparatus is then dismantled and its contents are analyzed as before. Repetitions of this procedure, with the displacement stopped after different amounts of glycerine have been introduced, yield data for diagrams like the others of Fig. 7. From these diagrams, the relative oil recoveries from the individual sands are computed.

Figs. 8 and 9 show these computed results. The properties of the model and its prototype are listed in Table 5. In this model, as in the radial one, the linear measurements of the model are one sixteenth those of the prototype. Thus, flooding out the 4-ft. column of mixed sands in 10 days in the model corresponds to flooding out 64 ft. of mixed sands in 40 days in the prototype.

Table 5.—*Properties of Sands and Fluids Used in Typical Linear Model*

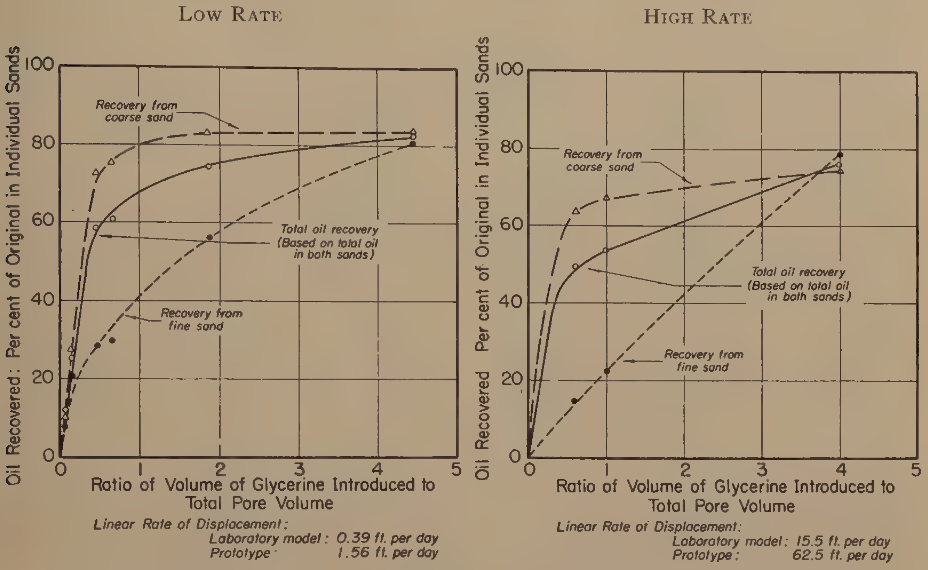
Fluids Used	Laboratory Model—S.A.E. 70 Lubricating Oil, Glycerine	Prototype—Oil, Water
Difference in density of fluids, grams per c.c.	0.366	0.366
Oil viscosity, cp.	795	1.99
Viscosity of aqueous phase, cp.	454	1.13
Interfacial tension, dynes per cm.	19.1	30.6
Total length of sand.	48 in.	64 ft.
Length of lens.	21 in.	28 ft.
Total width of sand.	4 in.	5.3 ft.
Width of lens.	3 in.	4 ft.
Porosity, average, per cent.	38	38
Permeability of coarse sand, darcys.	120	1.2
Permeability of lens, darcys.	8	0.08
Linear fluid velocity (high rate), ft. per day.	15.5	62.5
Linear fluid velocity (low rate), ft. per day.	0.39	1.56

Utility of Models

The radial model is particularly well adapted to studies of variations in well-completion methods. Present experiments are directed toward determining the variations in the produced water-oil ratio induced by setting the perforated section at various levels and by varying the length of the perforated section and the production rate. These data also will illuminate the phenomenon of water coning and its relation to production rate.

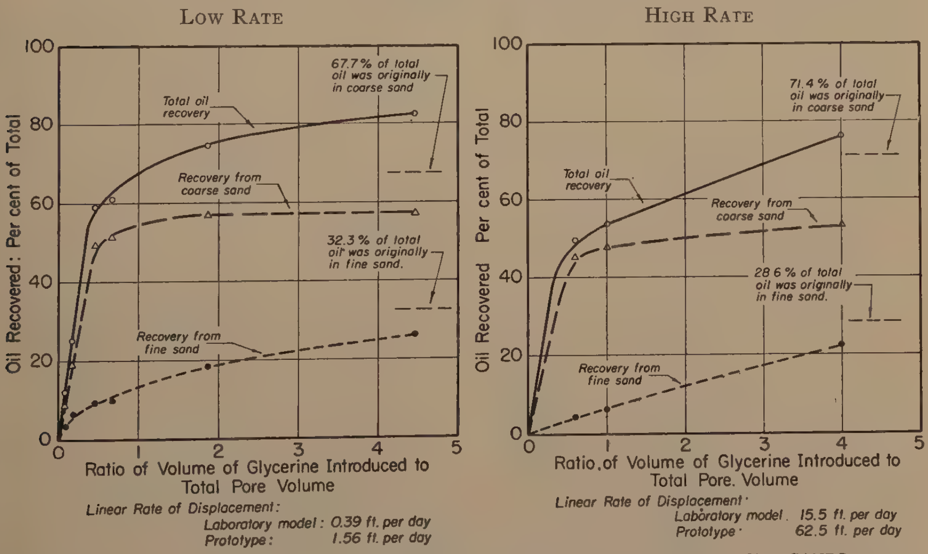
The linear model is designed to show the relationships among the factors affecting oil recoveries from layered sand in waterflooding.

It is clear that a large amount of work remains to be done in the field of applying our knowledge of mixture flow. The scaling


Low Rate

High Rate

FIG. 8.—EFFECT OF RATE ON WATER-DRIVE RECOVERY FROM NONUNIFORM SANDS.


Low Rate

High Rate

FIG. 9.—EFFECT OF RATE ON WATER-DRIVE RECOVERY FROM NONUNIFORM SANDS.

technique presented here appears to be a tool of fairly wide applicability, and its use should be considered wherever work of this sort is being done.

Further, the principles stated here imply that the results of experimental work on unscaled laboratory apparatus must be examined carefully to make sure that some apparently insignificant characteristic of the system has not been permitted to play a disproportionately important role, thus leading to erroneous interpretations. As an example, the boundary effect[4] is extremely important in experiments on short sand-flow tubes but is made to assume approximately its true significance in these models because of the dimensional principles on which they are built.

Acknowledgment

The authors are particularly indebted to Mr. S. E. Buckley for helpful suggestions in the preparation of this paper, and to Mr. H. W. Faulkner, who assisted with the experimental work.

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DISCUSSION

(*N. N. Jones presiding*)

G. Fancher,* Austin, Texas.—Petroleum engineering is coming of age when a paper like this can be prepared, presented and offered to the oil fraternity. This splendid paper is not only one that students of reservoir performance have awaited but also is a logical consequence of a type of research that has become increasingly significant during the past decade. The performance of models, including small oil fields, flooding pots and flow tubes of many kinds, has been studied by many workers since the pioneer days of Van Mills. Conclusions, conservative and rash, sound and controversial, theoretical and empirical, academic and practical, important and trivial, major and minor, have been drawn from these studies with no yardstick of reliability available except the slowly acquired lessons of experience. One cannot quarrel with this because certain tedious groundwork was necessary before the methods of Leverett and co-workers could be used. It should not be forgotten that dimensional analysis of a problem and the application of dimensional methods are absolutely dependent on a partial knowledge of the subject. In this case, a knowledge of the system involved had to develop, including the relations of permeability, porosity, fluid-phase properties, and rock systems. In other words, petroleum engineering had to come of age. Now, in the light of the methods of Leverett and co-workers, the results and conclusions of the earlier work with models should be examined critically. It is hoped that this will be done in order to plan better what remains to be done—and, more important, can and should be done soon.

Because the paper is largely a statement of methods rather than a report of results, little specific comment is required at this time. However, it is gratifying to those of us who have been using, for example, the variable (k/μ) in water-flooding work in an empirical way, and who have felt that results proved the point, now to have complete confidence in the basis of theory. It is perhaps somewhat of a blow to realize that a dimensional model of the smallest oil field, much less the East Texas field, is not to be realized, but at least there is consolation in the fact that, knowing this, our efforts can be directed to more promising fields of endeavor.

W. A. Bruce,* Tulsa, Okla.—In considering the statement that "for most clean unconsolidated sands the relative permeabilities are substantially independent of the properties of the sands or fluids," it may be well to note that in following the method of model design given in this paper it is necessary to assume that relative permeability-saturation relations are independent of sands or fluids. This assumption is logical and justifiable in pioneering an important piece of work like that presented here. It should be remembered, however, in attempting to apply results obtained with these models to actual reservoir problems, that, as pointed out by Dr. Leverett in an earlier paper, differences in relative permeability-saturation relations do exist even in clean unconsolidated sands, and that these differences are too large to be explained by experimental error.

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* The Carter Oil Co.

In the work on the dimensional inclusion of capillary pressure, the authors have taken a great step forward in removing one of the main obstacles; i.e., the necessity of having to use static capillarity experiments to consider dynamic problems. They have, by their rate of imbibition experiment, put the model work and capillary-pressure work on a comparable basis. It is to be inferred that more of this type of work will be done. It is important, though, to have experiments of a cross-check type also, to help prove the validity of this type of model work.

A possible experiment to do this could be along the lines of the rate of imbibition experiment described. It could be performed in such a way that imbibition rate vs. reciprocal linear advance of the "water front" would result. If the "water front" advance is similar to the static capillary distribution, there should exist the same driving pressure P_c, described by the authors, and the resistance of a column of fluid L in length and A in area. Thus, the rate of imbibition would be $q = P_cBA/L$. The experiment suggested above should give a straight line if P_c is constant, as is assumed in the representation given in Fig. 2. This would permit a consideration of the constancy of P_c for each sand considered rather than an assumption that P_c was a function of saturation surface tension and ϕ/K, since in this experiment K, ϕ, γ, and S would presumably be held constant.

M. C. LEVERETT (author's reply).—Dr. Bruce's suggestion that imbibition rate vs. reciprocal linear advance of the imbibed liquid should be a straight line was, in fact, considered as one possible way of presenting the data, and is approximately true. This procedure, however, was, found to be less satisfactory than the one used, which was to vary ϕ/K, γ, μ and S separately. In this way it was established that each of these factors enters into the P_c function in the manner shown in the paper.

Calculation of Productivity Factors for Oil-gas-water Systems in the Steady State

By H. H. Evinger* and M. Muskat*

(New York Meeting, February 1942)

A method of calculating productivity factors for oil, gas, and water systems in the steady state is presented as an illustration of the quantitative application of the fundamental data on the flow properties of heterogeneous fluid systems. While the numerical results of the calculations cannot be applied directly to field conditions, because they are based on permeability data for unconsolidated sands and involve specific assumptions regarding the nature of the reservoir fluids, the methods of analysis and interpretation should have significance in considering certain specific field situations when the necessary field and laboratory data become available. Moreover, it is felt that even under the idealized conditions to which the numerical calculations refer they should serve to give at least the orders of magnitude of the effects of gas-oil ratio and connate water on observed productivity factors. Within the indicated limitations, the computations imply that the foregoing factors can explain only a part of the apparent discrepancy between the homogeneous fluid productivity factors and those obtained recently in field measurements on the West Coast.

Introduction

Sufficient laboratory research has been carried out in the last several years on the fundamental features of the flow of heterogeneous fluids through porous media to call for consideration of what can be done with this type of information. It has, of course, already led to a much clearer general understanding of the mechanics of oil production. However, examples of the quantitative application of the results of such laboratory studies are few in the literature. Part of the explanation for this fact lies undoubtedly in the lack of sufficient laboratory data relating to practical fluids and sand systems such as would occur in actual oil reservoirs. However, unless it can be shown that if such data were obtained quantitative applications could be made, serious doubt may be cast upon the desirability of carrying on further extensive experimental research work on fluid flow.

The purpose of this paper is to present one approach to the problem of quantitative application of laboratory data to practical field problems. Because the published results on the basic experiments with three-phase fluid systems in porous media are limited entirely to unconsolidated sands, the numerical applications made here will not pertain directly to any actual field situation. However, they should serve to illustrate what could be done with fundamental laboratory data if they were extended to cover the field of consolidated sands. From this point of view, it is hoped it will serve to encourage further laboratory research on this problem.

The particular application to be treated here relates to the calculation of the productivity factors for oil-gas-water systems in the steady state. This specific problem seems especially appropriate for discussion in view of the recent publication by Johnston[1] of the results of produc-

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[1] References are at the end of the paper.

tivity-factor measurements in California (see also Pyle and Sherborne[2]). These measurements indicated that the productivity factors as determined in the field are generally very much smaller, by factors of 50 to 100, than those calculated on the radial homogeneous fluid flow formula. As Johnston points out, it is to be expected that the homogeneous fluid formula will predict productivity factors higher than those that will be observed in practical field tests where the fluid system is multiphase. It is stated, in fact, that the apparent discrepancy involving the factors of 50 to 100 must arise from the heterogeneous nature of the flow system in the actual field reservoirs and the quality of the well completion. It is obviously pertinent to inquire how much of the apparent discrepancy can be attributed to the multiphase characteristics of the flow systems. The treatment to follow represents the results of such an inquiry. Admittedly its significance is limited because it has of necessity been based upon data obtained from unconsolidated sands.[3] Moreover, the fluid system assumed in the numerical part of the work undoubtedly differs to some extent from those involved in the actual field tests. Nevertheless, it is felt that the calculations are useful in indicating the order of magnitude of the effect that may be attributed to the multiphase features of the flow system. In any case they should serve to show how the proper calculations could be carried out if and when the appropriate practical laboratory data on consolidated sands become available.

ANALYTICAL PROCEDURE

The analytical basis for the following calculations is the generalization of that previously developed and applied in the study of two-phase systems flowing through porous media.[4] For the general case of a three-phase system such as gas, oil and water, the dynamical equations are obtained by writing an equation of continuity for each of the three phases, as follows:

$$\nabla \cdot \left(\frac{k_o}{\beta \mu_o} \nabla p \right) = f \frac{\partial}{\partial t} (\rho_o / \beta) \qquad [1a]$$

$$\nabla \cdot \left(\frac{S}{\beta} \frac{k_o}{\mu_o} \nabla p + \frac{\gamma k_g}{\mu_g} \nabla p \right) = f \frac{\partial}{\partial t} \left\{ \frac{S \rho_o}{\beta} + \gamma (1 - \rho_o - \rho_w) \right\} \qquad [1b]$$

$$\nabla \cdot \left(\frac{k_w}{\mu_w} \nabla p \right) = f \frac{\partial \rho_w}{\partial t} \qquad [1c]$$

where k, μ and ρ denote, respectively, permeability, viscosity, and saturation, and the subscripts o, g and w refer to the oil, gas and water phases; p denotes the fluid pressure, f the porosity, γ the gas density and S the solubility of the gas in the oil expressed as volume of gas dissolved per unit volume of residual oil. β represents the expansion factor of the oil, and for any particular pressure it is equal to the volume occupied by unit volume of residual oil. In setting up these equations, it has been assumed that both the solubility of the gas in the water and the expansion of the water may be neglected.

If the assumption is introduced that the flow takes place under steady-state conditions, which might be regarded as justifiable for short periods of time, the right sides of Eqs. 1a, 1b and 1c become zero and their first integrals may be obtained easily. Equating the left members of these equations to zero, the first integrals for a radial system are given by:

$$Q_o = \frac{2\pi r h}{\beta} \frac{k_o}{\mu_o} \frac{dp}{dr} \qquad [2a]$$

$$Q_g = 2\pi r h (S k_o / \beta \mu_o + \gamma k_g / \mu_g) \frac{dp}{dr} \qquad [2b]$$

$$Q_w = 2\pi r h \frac{k_w}{\mu_w} \frac{dp}{dr} \qquad [2c]$$

where Q represents volume rates of production, the units being cubic centimeters of residual oil per second for the oil phase and of gas (reduced to standard conditions) per second for the gas phase.

Denoting the gas-oil ratio Q_g/Q_o by R, and the water-oil ratio Q_w/Q_o by W, it is found from Eqs. 2, by simple division, that:

$$R = S + \alpha(p)k_g/k_o \qquad [3a]$$

and

$$W = \Phi(p)k_w/k_o \qquad [3b]$$

where:

$$\alpha(p) = \gamma\beta\mu_o/\mu_g \quad \text{and} \quad \Phi(p) = \beta\mu_o/\mu_w \qquad [4]$$

It should be noted here that α and Φ are properties of the fluid system and are functions of p alone (for isothermal conditions), whereas the permeabilities, k, are properties of the porous medium and are determined by the saturations ρ_w and ρ_o.

Direct integration of Eq. 2a gives:

$$\frac{Q_o}{2\pi hk} \log r_e/r = \int_p^{p_e} \frac{k_o/k}{\mu_o\beta}\, dp \qquad [5]$$

where p_e is the reservoir pressure, r_e the effective reservoir radius, and k the homogeneous fluid permeability. The indefinite integral may be evaluated, as was done for the two-phase system, and the pressure distribution may be determined. However, it will be sufficient for the calculation of the productivity factor to consider only the limiting form of Eq. 5 obtained by putting $r = r_w$, $p = p_w$, and then letting p_w approach p_e. Eq. 5 then takes the following form:

$$\frac{Q_o}{hk\Delta p} = \frac{2\pi(k_o/k)_e}{\mu_o\beta \log r_e/r_w} = F \qquad [6]$$

where F is the productivity factor, $(k_o/k)_e$ is the relative permeability to oil corresponding to the sand saturation at the reservoir radius, and r_w is the well radius. The values of μ_o and β to be used in numerical calculations are those corresponding to the reservoir pressure. From Eq. 6 it is clear that, so far as the effect of fluid saturation is concerned, the term $(k_o/k)_e$ alone will cause variations in F. For the case in which the pore space is completely filled with oil, this term has the value unity. If free gas or connate water is present, however, its value will be lowered. This effect is shown in some of the accompanying curves.

Several items should be noted with respect to the definition of the productivity factor as given by Eq. 6. In the first place, it has been defined so as to refer to the limiting slope of the production-rate vs. pressure-differential curve for vanishing pressure differential; that is, at the origin. This special form for the definition has been used here because the theoretical calculations, as made previously for the two-fluid system, and as would be implied by Eq. 5 for the three-fluid system, lead to a nonlinear variation of the production rate with pressure differential. Thus, the productivity factor, as ordinarily defined, which involves division of the production rate by the pressure differential, would not be constant, but would decrease as the production rate increases. It is necessary therefore, from a theoretical point of view at least, to refer the productivity factor to some basic reference point, and the most natural reference basis seems to be the limiting conditions at vanishing pressure differential. From a practical standpoint this means that if there is any pronounced curvature in the curve of observed production rate vs. pressure differential the curve should be extrapolated to the origin and its slope at that point be used in calculating the productivity factor.

Another factor to be noted about the definition of Eq. 6 relates to the reduction of the productivity factor to unit sand thickness, thus removing the effect of the absolute value of the thickness of the producing zone. This corresponds to the specific productivity factor that has already appeared in the literature. Where no difficulties arise from the linear averaging of strata of different effective permeabilities, the over-all productivity factors for a natural system should be given simply by the product of the F values of Eq. 6 and the effective sand thickness.

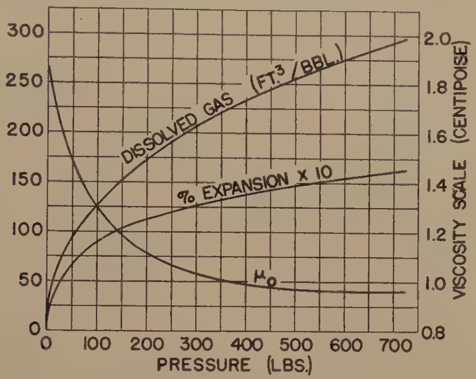

Fig. 1.—Solubility, expansion factor, and oil viscosity for reservoir fluids as a function of reservoir pressure (gauge).
Expansion factors are equivalent to $\beta - 1$.

The expression of F in terms of a unit permeability has likewise been introduced only to avoid the assumption of specific numerical values for the permeability. This is not to be construed as implying that the relative permeability curves for the various fluid phases are the same for all sands regardless of the homogeneous fluid permeability. On the contrary, it is to be understood that the only way in which quantitative checks between field and laboratory computations of the productivity factors can be made is by using for the relative oil permeability, (k_o/k), data appropriate to the particular producing pay in question. The reduction of the productivity factor to a unit permeability will then be only a matter of convenience and convention, and, in fact, the use of Fk rather than F for the productivity factor would then probably be more advisable from a practical point of view.

Again it is to be emphasized that these various simplifying factors of the definition of Eq. 6 can be justified only because the calculations as a whole are intended to serve essentially as an illustration of the method of calculating productivity factors. It is to be understood, however, that when the necessary data for specific cases are available the simplifications can be dropped and the appropriate modifications can be made in the calculations. To avoid misinterpretation, explicit values of F will not be presented here, and the numerical values will be limited to those of k_o/k which give the ratio of the productivity factor for the multiphase system to that for the equivalent homogeneous fluid system.

Experimental Data

The properties of the oil used in these calculations are the same as those employed in the previous work[4] on the low-pressure, two-phase system. Fig. 1 gives the variation with pressure of the gas solubility S, oil expansion β, and oil viscosity μ_o. For the gas, the viscosity was assumed to be constant at 0.01 c.p., and its density was taken to be proportional to the absolute pressure. The permeability-saturation data are shown graphically in Figs. 2, 3, 4 and 5. These curves were obtained, by means of a great deal of smoothing and interpolation, from the data of Leverett and Lewis.[3] As already indicated, the porous media employed in their experiments consisted of unconsolidated sands, and inasmuch as no similar work has been published on consolidated sand there exists an uncertainty as to the extent to which the final calculations might be influenced by differences in the properties of the sand. Another factor that tends to limit the usefulness of these data is the scarcity of measurements for values of water saturation between 0 and 30 per cent. This is a rather important range because it includes the cases in which the connate-water content may be sufficient to decrease the oil permeability considerably and yet be too low to result in the production of water.

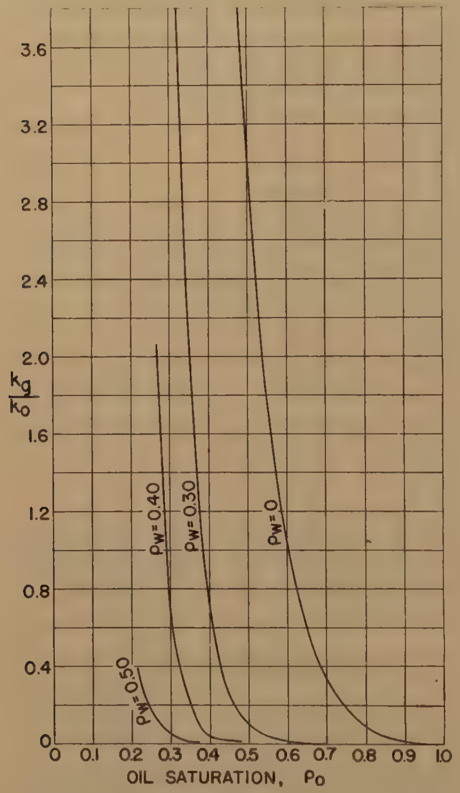

Fig. 2.—Variation of k_g/k_o with oil saturation (ρ_o) for fixed values of water saturation (ρ_w).
k_g = gas permeability; k_o = oil permeability.

In Fig. 2 are plotted curves of the ratio of gas to oil permeability, k_g/k_o, vs. the oil saturation ρ_o, for constant values of the water saturation ρ_w. Eq. 3 shows that for fixed reservoir pressure the gas-oil ratio varies linearly with k_g/k_o. The curve for $\rho_w = 0$ was taken from the work of Wyckoff and Botset[5] because the data for this case were much more complete than those of Leverett and Lewis. For fixed water saturation ρ_w, k_g/k_o decreases with increasing oil saturation, which, of course, is to be expected, since the gas permeability should decrease and the oil permeability increase as ρ_o becomes larger. The effect of increasing the water saturation for fixed oil saturation is to decrease the ratio k_g/k_o. Probably this is chiefly because k_g itself decreases on account of the necessarily decreasing values of the gas saturation. Fig. 3 shows similar curves for the ratio of water to oil permeabilities, k_w/k_o, which is pro-

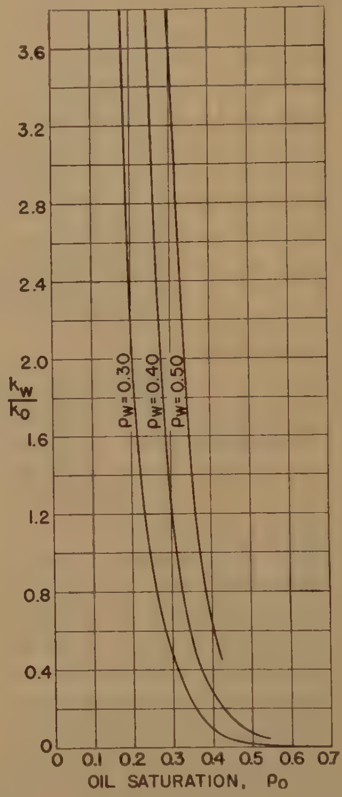

Fig. 3.—Variation of k_w/k_o with oil saturation (ρ_o) for fixed values of water saturation (ρ_w).
k_w = water permeability; k_o = oil permeability.

portional to the water-oil ratio of the production. The general characteristics of these can be explained by considerations similar to those applied to Fig. 2.

Fig. 4 shows the variation of relative permeability to oil, k_o/k, with the ratio k_g/k_o for fixed values of ρ_w. Again, Wyckoff and Botset's data were used for the case $\rho_w = 0$. The curves of Fig. 5 were obtained by cross plotting the curves of Fig. 4, the odd values of k_g/k_o corresponding to the values of gas-oil ratio R assumed in the subsequent calculations.

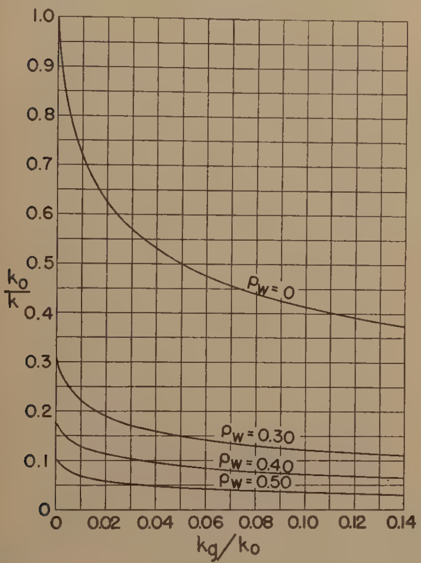

FIG. 4.—VARIATION OF RELATIVE PERMEABILITY TO OIL (k_o/k) WITH k_g/k_o FOR FIXED VALUES OF WATER SATURATION (ρ_w).

k = homogeneous-fluid permeability; k_g = gas permeability; k_o = oil permeability. k_o/k is equivalent to ratio between productivity factor for actual flow system and that for corresponding homogeneous-fluid system.

NUMERICAL APPLICATION

The first step in the application of these data was to determine the reservoir saturations ρ_o and ρ_w, required to yield specified values of gas-oil ratio R and water-oil ratio W. The range of numerical values employed was 0 to 5 bbl. water per barrel oil for W, and 297 to 2000 cu. ft. per barrel* oil for R, the figure of 297 representing the saturation value at the assumed reservoir pressure of 725 lb. per sq. in. From the assumed values of R and W, k_g/k_o and k_w/k_o were determined by means of Eqs. 3a and 3b. Then, using the resulting values of k_g/k_o and k_w/k_o, it was possible, by the use of the curves of Figs. 2 and 3, to make a graphical determination of ρ_w and ρ_o. With ρ_w known, the relative permeability to oil, k_o/k, corresponding to the selected value of R, was determined from the appropriate curve of Fig. 5.

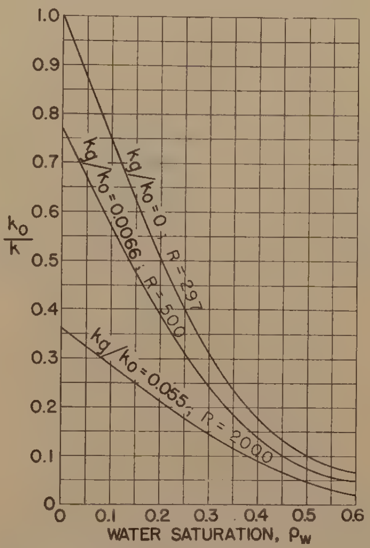

FIG. 5.—VARIATION OF RELATIVE PERMEABILITY TO OIL (k_o/k) WITH WATER SATURATION (ρ_w), FOR FIXED VALUES OF k_g/k_o, OR GAS-OIL RATIOS R.

k = homogeneous-fluid permeability; k_g = gas permeability; k_o = oil permeability; k_o/k = (productivity factor for actual system)/(productivity factor for corresponding homogeneous-fluid system).

It is thus possible, if the properties of the gas-oil mixture are known, to determine the values of ρ_w and ρ_o (and also ρ_g, since $\rho_w + \rho_o + \rho_g = 1$), which will yield specified values of R and W. The permeabilities for each phase can then be found from the permeability-saturation data. It should be noted here that the numerical values of permeability and saturation found in this manner refer to conditions at r_e, the reservoir boundary. If it were desired, the radial distribution of these quantities could be found as a function of the pressure differential in a manner similar to that employed for the two-phase system. For the purpose of the limiting productivity-factor calculation, however, this is unnecessary.

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* Gas-oil ratios higher than the solution ratio are used here only for illustrative purposes. In practice such a situation would imply that the original pressure was considerably higher than 725 lb. per sq. in. and that the sand has already been appreciably depleted.

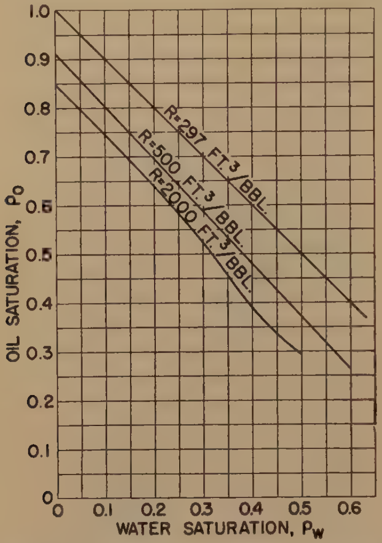

FIG. 6.—VARIATION OF OIL SATURATION (ρ_o) WITH WATER SATURATION (ρ_w) FOR FIXED VALUES OF GAS-OIL RATIO R.

The numerical results of the procedure described above are presented in graphical form in Figs. 6 to 9. Fig. 6 gives the relation between the limiting reservoir values of ρ_o and ρ_w for fixed values of the gas-oil ratio. For the case $R = 297$, all of the gas is carried in solution in the oil, at the reservoir radius, and the curve merely expresses the relationship $\rho_o + \rho_w = 1$. The fact that all of the curves are approximately of the form $\rho_o + \rho_w + c = 1$, where c is a constant, shows that the gas saturation ρ_g is determined essentially by the gas-oil ratio R. The curves of Fig. 7 are obtained directly from those of Fig. 6, and show the relationship between the gas-oil ratio and oil saturation for fixed values of water saturation. As is to be expected, R increases rapidly for decreasing values of ρ_o. As ρ_o decreases with a fixed value of ρ_w, ρ_g must necessarily increase. This results in an increase in k_g and a decrease in k_o. Eq. 3*a* shows that this leads to an increase in the value of R.

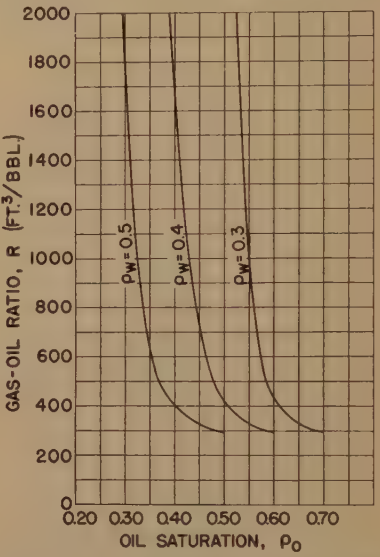

FIG. 7.—VARIATION OF GAS-OIL RATIO R WITH OIL SATURATION ρ_o FOR FIXED VALUES OF WATER SATURATION ρ_w.

In Fig. 8 the relationship is plotted between the water-oil ratio W and ρ_w for fixed values of R. Eq. 5*b* shows that W is determined essentially by the ratio k_w/k_o. In the discussion of Fig. 6 it was shown that a constant value of R implies only a small variation in the gas saturation ρ_g so that an increase in ρ_w for fixed R necessitates a decrease in ρ_o. The ratio k_w/k_o, and hence W, will therefore increase with ρ_w not only because of the increase in k_w but also because of the decrease in k_o. In Fig. 9 are shown curves of W vs. ρ_o/ρ_w for fixed values of R. Here, as is to be expected, increasing values of ρ_o/ρ_w give rise to a decrease in water-oil ratio. One feature of these curves to be noted is that for a particular value of ρ_o/ρ_w, W is relatively insensitive to changes in R. Thus, when R is increased by a factor of nearly seven, the maximum change in W, for the range covered by the curves, is less than a factor of three.

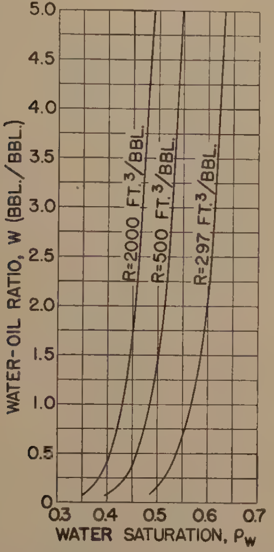

FIG. 8.—VARIATION OF WATER-OIL RATIO W WITH WATER SATURATION ρ_w FOR FIXED VALUES OF GAS-OIL RATIO R.

APPLICATION TO PRODUCTION PROBLEMS

The foregoing analysis has shown that with the gas-oil ratio and water-oil ratio given, it is possible, in principle, to calculate the reservoir saturations ρ, and hence the permeabilities and productivity factor. Conversely, if one knew the reservoir saturations, the gas-oil ratio, water-oil ratio and the productivity factor could be found. The determination of the reservoir saturations is one of the central problems of core analysis, of course. In virgin fields the determination of the interstitial water from cores in the oil-water zone should, by difference, give reliable values for the oil saturation. For depleted reservoirs, however, even more indirect methods must be used in the determination of the oil saturation, so that a greater uncertainty may be involved in the final calculation of the productivity factor.

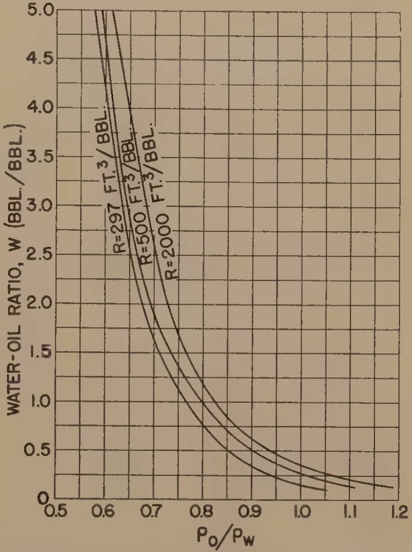

FIG. 9.—VARIATION OF WATER-OIL RATIO W WITH ρ_o/ρ_w FOR FIXED VALUES OF GAS-OIL RATIO R. ρ_o = oil saturation; ρ_w = water saturation.

If we suppose that the reservoir saturations ρ_o and ρ_w have been determined, the corresponding value of k_g/k_o may then be found from curves such as those of Fig. 2. Curves such as those of Fig. 4 will then provide the relative permeability to the oil, k_o/k. Since the composite effect upon the gas and water phases on the oil flow is included in the value of k_o/k, Fig. 4 should then give the productivity factors of the three-phase system relative to that for a homogeneous fluid system.

It is of interest to note that the numerical results corresponding to the preceding figures would suffice to explain only a part of the large differences reported by Pyle and Sherborne[2] and Johnston[1] between the observed values of the productivity factor and those calculated on the basis of the homogeneous fluid permeability. In fact, even for cases in which ρ_w is sufficiently large to give rise to a 10 per cent water production the relative permeability to oil k_o/k still exceeds 0.1. On the other hand, for some of the cases cited by Pyle and Sherborne and by Johnston this ratio would be less than 0.01, notwithstanding the fact that the wells were producing only negligible amounts of water. It is, of course, true, as has been previously emphasized, that the numerical calculations reported here refer to a specific fluid system with a fixed reservoir pressure of 725 lb. And, what is more important, the permeability data relate only to the unconsolidated sands studied by Leverett and Lewis.[3] Undoubtedly, the numerical results of the calculations would be different if the corresponding data for consolidated sands had been used, and, in fact, they would be likely to vary with each particular type of consolidated sand. However, in view of the low values of the relative oil permeability already used in the calculations, even with the unconsolidated sand, as shown in Fig. 4, it seems very doubtful whether the whole of the residual discrepancy could be bridged merely by corrections in the assumed permeability curves.

The alternative to attributing the discrepancy to approximations in the theoretical calculations appears to lie in the physical significance of the field observations. This alternative, however, is also beset with difficulties. Thus the failure to reach strictly steady states in the field tests should have led to apparent productivity factors greater than those calculated, rather than lower. The use here of a limiting productivity factor, for zero pressure differential, in contrast to the conventional usage, in which the production rate is divided by the nonvanishing pressure differential, would tend to make the field results low. However, this difference could account at most for a factor of 2 in the discrepancy. One is thus forced to raise the question of mudding or plugging of the producing sand faces during the well completion as the reason for the abnormally low productivity factors observed in the field tests. This, of course, is admittedly too broad an explanation to be especially convincing. For one might have expected more exceptions with high productivity factors, corresponding to really clean sand faces, among all the wells studied. On the other hand, there is a considerable spread—corresponding to a factor of 5 to 10—in the data plotted by Johnston, which is suggestive of an erratic element in the data, such as would be expected of mudding effects.

The implications of these calculations that the field results as reported by Johnston cannot be entirely explained in terms of the heterogeneous character of the oil and gas seems to be strongly supported by the data recently reported by Horner, Lewis and Stekoll.[6] These authors find that the ratios between the productivity factor as calculated by the homogeneous fluid formula and those observed are in general even less than 2 and occasionally agree with the value unity within experimental errors. On the basis of these results, it would seem that under field conditions the heterogeneous character of the flow may affect the productivity factor far less, rather than more, than would be indicated by the present calculations. While it is true that many of the cases cited by Horner, Lewis and Stekoll refer to virgin conditions with practically no free gas voidage within the sand, even those where free gas was present required no more than a factor of 2 as a correction to bring the observed results in line with those obtained under virgin conditions. In the latter, of course, the major factor reducing the permeability to the oil was the connate water. Hence, at least for the wells studied by these authors, the connate water did not appear to cut down the productivity factor to less than half of the ideal homogeneous fluid value. To achieve a satisfactory reconciliation between these divergent results, it is therefore clear that further work needs to be done with respect to the gathering of both laboratory and field data.

Aside from the bearing of the foregoing calculations on the problem of productivity factors, other interesting conclusions may be drawn. Thus Fig. 7 shows the rapid increase of the gas-oil ratio with decreasing oil saturation. This does not mean a corresponding increase in gas-oil ratio with increasing cumulative oil production, since Fig. 7 is based on the assumption that the reservoir pressure is kept fixed at 725 lb. On the other hand, it does indicate the relatively low efficiency of direct gas drive in repressuring as a secondary-recovery operation.

A very high sensitivity of the water production—water-oil ratio—to the water saturation may be inferred from Fig. 8. This is at least qualitatively in accord with the field experience that the transition period between the flow of clean oil and complete drowning out of the oil by water is often of very short duration. Of course, the basic permeability saturation data of Fig. 4 directly indicate this type of behavior.

ACKNOWLEDGMENT

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Factors Influencing Electrical Resistivity of Drilling Fluids

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(Los Angeles Meeting, October 1941)

The relation between the properties of electric logs and the fluid used in drilling a well is briefly discussed in this paper, and the fact that the resistivity of the drilling mud and its filtrate can appreciably affect such logs is shown.

Apparatus was designed and a procedure established to determine the effect of various factors on the resistivity of drilling mud. Five muds commonly employed in California were tested and the following observations were made:

1. The effect of raising the temperature from 80°F. to 180°F. is to decrease the resistivity of the mud or filtrate approximately 50 per cent.
2. The resistivity of the mud in most cases closely approximates that of its filtrate.
3. The change in the resistivities of muds caused by the addition of chemical is not the same function of the amount of chemical added for each mud.
4. The effect produced by increased sodium chloride content is to reduce markedly the resistivity of the mud and its filtrate.
5. Weighting materials, such as Baroid and limestone, tend to increase the resistivity of drilling mud.
6. Cement and counteracting reagents reduce mud resistivity.

Introduction

During recent years, the practice of "electrically logging" a geologic formation by means of a system of electrodes lowered in a well bore has provided data of inestimable value concerning the nature of the sediments penetrated. Thus, it is generally possible, by means of electric logs, to distinguish readily the differences between shales, sandstones, cherts, limestones, and other rock forms. The distinguishing characteristics recorded in this manner have made possible long-range and closely detailed mapping and visualization of deeply buried structures[1–5] to a degree not to be obtained with a reasonable expenditure of money by any other means at present in use.

Besides being of value in correlation work, electric logs have been found, in some instances, to be useful in estimating the nature of fluid contained within the pores of a rock. In special cases, even the relative permeabilities at different horizons have been determined.[6] That electric logs should reflect in some measure such physical properties of rocks as porosity and permeability and, in addition, give rise to data pertaining to the fluid content of rock interstices, becomes evident when the conditions giving rise to the electrical phenomena measured are known. However, it is not the purpose of this paper to review the present status of electric logging; rather, the reader is referred to the papers cited on page 220 for the principles and practice involved.

Importance of Drilling Fluid in Electric Logging

Because the drilling fluid must be the medium through which the electric logging device is made to traverse the formations penetrated by a borehole, and since, in general, the drilling mud completely surrounds

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[1] References are at the end of the paper.

the electrodes, a knowledge of the electrical properties of this fluid is essential to the thorough analysis of electric logs. There have long been considerable field data to indicate the great influence of the nature of the drilling fluid upon electric logs, but, to the knowledge of the writers, no quantitative information has been published. As has been indicated above, the resistivity of a drilling mud, the resistivity of its filtrate, and the wall-building characteristics of the mud are three of its more important qualities, as far as electric logging is concerned. The latter quality, the wall-building character, is important in that it controls, to some extent, the amount of fluid infiltration into the formation. As has been shown by Torrey,[6] the self-potential curve can yield valuable information regarding the permeability of the formations encountered when the fluid entering the formation is allowed to pass directly from the well bore into the formation without encountering resistance. When mud is used, however, that is not generally true. Drilling mud is so composed and maintained that very quickly it builds a relatively impervious cake upon the walls of the borehole. A mud similar to the muds of good quality used in practice, when circulated against formations widely different in their properties, will produce a cake that has a very low permeability in comparison with that of the formation. H. T. Byck[11] studied a number of muds and found that the permeabilities of their cakes were of the order of 10^{-6} darcys, whereas those of sands encountered in oil-bearing formations range from as low as 10^{-3} to as high as 25 darcys.* It is apparent that the mud cake, in most instances, must, to a large extent, control the rate of flow of fluid from the well bore into the formation. The wall-building characteristics of drilling fluids have been considerably investigated.[11–12] However, as far as the writer knows, very few data have been accumulated regarding the resistivity of the drilling fluid and its filtrate or the factors that influence it.

Scope of Investigation

The purpose of this paper is, first, to present a report of the apparatus used and results obtained in a brief investigation into the effect that various factors may have upon the electrical resistance of drilling muds and their filtrates, and, second, to show the effect of the electrical resistance of the drilling fluid upon electric logs in some specific cases.

Measurements were made over a range of conditions usually encountered in ordinary field operations. The tests were made at temperatures from 80°F. to 180°F. The conditions were maintained to within ±0.5°F. at the lower temperature and within ±2.0°F. at the higher temperatures, by means of a water bath.

Materials Used

Five muds were chosen for this study, closely representing the various types used in oil-well completions in California. These muds are designated as McKittrick, Aquagel, Oxo, Wilmington Slough, and Mojave P-34. Their properties are given in Table 1.

Table 1.—*Properties of the Five Muds Tested*

Mud	Weight, Lb. per Cu. Ft.	Salinity, Grains per Gal.	pH	Filter Rate, 5–15 Min. Difference, C.C.
Aquagel	64.9	7	9.2	4.5
McKittrick	80	14.4	9.0	
Oxo	75.7	15.4	8.7	5.3
Mojave P-34	85	92		
Wilmington Slough	69.6	292		

The relation between temperature and resistivity for the five muds and their filtrates, both native and treated with sodium pyrophosphate, quebracho (commercial tannic acid), sodium chloride, Baroid, limestone, cement, and sodium bicarbonate, has been determined. Each of these materials was of the grade that would be used to treat the mud in the field. The amounts used were so chosen as to cover the range of the ordinary practical application, although, in some of the tests, particularly chemically treated samples, large excesses were added to demonstrate more clearly the effect produced.

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* The unit of permeability, the darcy, is the value obtained when a homogeneous fluid flows at a rate of one milliliter per second, through one square centimeter of a porous medium, under a pressure gradient of one atmosphere per centimeter, for conditions of viscous flow.

Both Baroid (essentially barium sulphate) and limestone are used in a very finely divided state as weighting material in drilling muds. Since the state of aggregation of these solids determines to some extent the properties of the mud, a particle-size determination was obtained for each (Table 2).

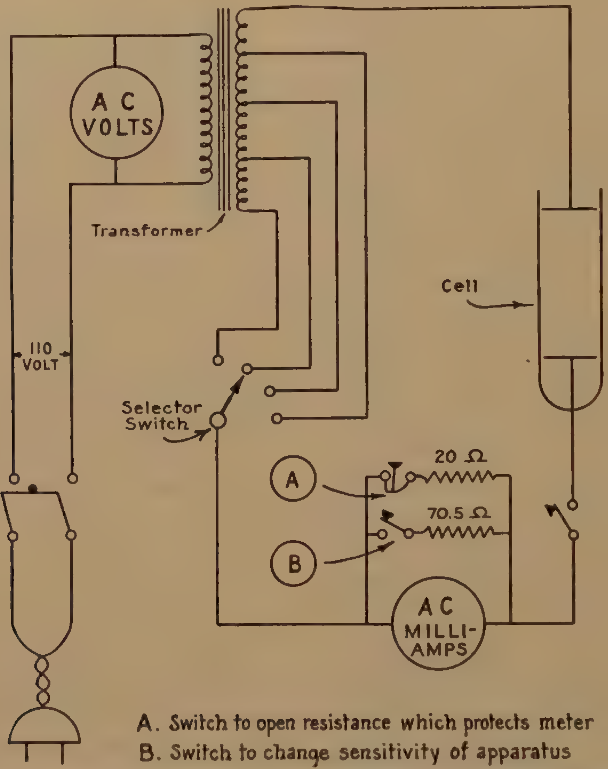
A C VOLTS
Transformer
110 VOLT
Selector Switch
Cell
20 Ω
70.5 Ω
A
B
A C MILLI-AMPS
A. Switch to open resistance which protects meter
B. Switch to change sensitivity of apparatus

FIG. 1.—SCHEMATIC DIAGRAM OF METER CIRCUIT EMPLOYED IN RESISTIVITY MEASUREMENTS.

APPARATUS

The Meter.—Since the instrument used in making these determinations was designed for use in the field by men with little technical training, consideration was given to making the device both strong and simple to operate, therefore certain refinements usually found on laboratory apparatus were omitted. However, the results obtained are felt to be well within the limits required by field conditions. The circuit is very simple and consists of a multitapped transformer fed by a source of electricity, the potential of which is given by an a.c. voltmeter across the primary. Current is withdrawn from a selected portion of the secondary and flows through a cell containing the material to be tested. An a.c. milliammeter in series with the cell is used to determine the resistivity. Various resistances are used to change the range of the meter and to protect it. A schematic diagram of the circuit is shown in Fig. 1.

The Cell.—It is impracticable in the field to measure the resistivity of a mud at a predetermined temperature but for laboratory measurements the making of tests at constant temperature is highly desirable. Therefore, it was necessary to develop cells for both the field and the laboratory. As with the meter, effort was made to make the cell for field use as strong as possible; the body and cap are made of Bakelite and the plates of stainless steel. A sketch of this cell is shown in Fig. 2.

Two cells were used for the laboratory determinations, one for the mud, the other for the smaller amount of filtrate obtained from the mud. Both of these cells were made of Pyrex and employed stainless-steel plates as electrodes. The laboratory cells were very similar in construction except for size. When once a cell had been calibrated, great care was taken to keep each of the plates properly oriented in relation to the other. During the experiments, the laboratory cells were maintained at constant temperature by immersion in a water bath.

TABLE 2.—*Particle-size Distribution*

Mesh or Particle Size	Baroid,[a] Per Cent by Wt.	Limestone, Per Cent by Wt.
Pass 100 mesh	100	100
Pass 150 mesh	100	99
Pass 200 mesh, smaller than 74 microns	100	95.5
Pass 325 mesh, smaller than 44 microns	98	86.0
Smaller than 40 microns	84.1	
Smaller than 30 microns	72.1	
Smaller than 20 microns	53.1	
Smaller than 15 microns	42.6	
Smaller than 10 microns	31.6	
Smaller than 8 microns	28.1	
Smaller than 5 microns	17.5	
Smaller than 4 microns	14.0	
Smaller than 2 microns	6.9	
Smaller than 1 micron	3.2	
Smaller than 0.5 micron	0.8	
Specific gravity	4.5	2.7

[a] Material and data obtained from Baroid Sales Corporation, Los Angeles.

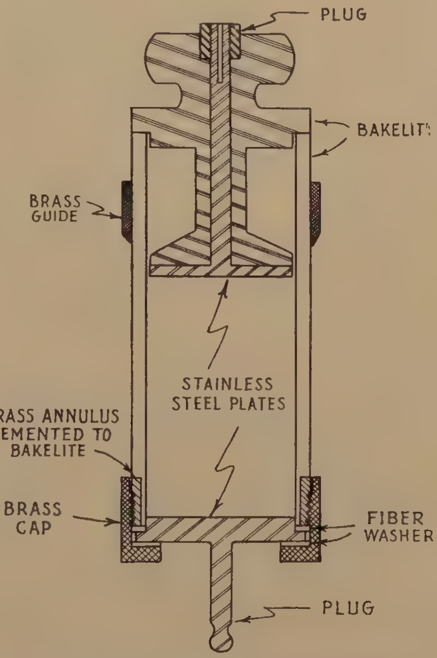

FIG. 2.—CELL USED FOR FIELD MEASUREMENTS.

The Filter Press.—The apparatus used to obtain the filtrate is that developed by P. H. Jones,[13] which has been widely accepted throughout the petroleum industry for determining the filter performance of drilling fluids.

CALIBRATION OF APPARATUS

The apparatus was calibrated by tests made with chemically pure potassium chloride solutions of known concentration. The relation between the normality of these solutions and resistance was determined by data obtained from the International Critical Tables. During these and all subsequent tests, corrections were made for differences in line voltage observed on the voltmeter across the input of the transformer.

TABLE 3.—*Effect of Chemical Treatment on Resistivity*

AQUAGEL, MOJAVE P-34, WILMINGTON SLOUGH MUDS AND FILTRATES[a]

Sample No.	Treatment	Mud		Filtrate	
		Temperature, Deg. F.	Resistivity, Meter-ohms	Temperature, Deg. F.	Resistivity, Meter-ohms
AQUAGEL MUD AND FILTRATES[a]					
1	None	80	7.8	83	10.2
		101	6.4	98	8.2
		121	5.1	138	6.1
		140	4.5	178	4.2
		157	3.9		
		177	3.4		
1A[b]	None	177	3.4		
2	2 lb. per bbl. sodium pyrophosphate	80	1.8	82	1.9
		100	1.4	100	1.5
		138	1.0	146	1.05
		180	0.76	179	0.85
3	2 lb. per bbl. quebracho	80	5.7	84	5.0
		100	4.4	102	4.3
		140	3.1	142	3.0
		180	2.5	178	2.3
4	2 lb. per bbl. each sodium pyrophosphate and quebracho	81	1.6	82	2.1
		104	1.3	101	1.6
		139	0.95	137	1.2
		180	0.74	180	0.85
4A[b]	Same as No. 4	84	1.6		
		120	1.1		
		136	0.93		
		175	0.72		
5	5 lb. per bbl. each sodium pyrophosphate and quebracho	82	1.1	80	1.3
		104	0.82	98	1.1
		139	0.63	144	0.75
		180	0.53	180	0.55
MOJAVE P-34 MUD AND FILTRATES[c]					
1	None	80	2.0	82	1.7
		101	1.6	101	1.4
		140	1.2	140	0.95
		180	0.87	179	0.75
1A[b]	None	179	0.87		
2	2 lb. per bbl. sodium pyrophosphate	84	1.3	80	1.0
		100	1.0	101	0.82
		140	0.72	140	0.62
		181	0.61	181	0.43
3	2 lb. per bbl. quebracho	81	2.0	80	1.7
		102	1.5	100	1.4
		139	1.2	146	0.92
		180	0.86	181	0.71
4	2 lb. per bbl. each sodium pyrophosphate and quebracho	80	1.3	80	1.3
		100	1.0	101	0.99
		119	0.84	139	0.71
		178	0.62	177	0.58
4A[b]	Same as No. 4	82	1.3		
		100	1.0		
		140	0.71		
		180	0.59		
5	5 lb. per bbl. sodium pyrophosphate	82	0.87		
		98	0.74		
		140	0.53		
		178	0.46		
5A[b]	Same as No. 5	81	0.86		
		106	0.63		
		142	0.52		
		182	0.38		
6	5 lb. per bbl. each sodium pyrophosphate and quebracho	82	1.0	85	0.78
		102	0.83	103	0.64
		142	0.59	138	0.48
		180	0.49	178	0.37
6A	Same as No. 6			86[d]	0.65[d]
				101[d]	0.57[d]
				139[d]	0.42[d]
				176[d]	0.35[d]
WILMINGTON SLOUGH MUD AND FILTRATES[e]					
1	None	80	0.95	80	0.88
		100	0.76	101	0.70
		140	0.57	120	0.57
		178	0.46	178	0.40
2	2 lb. per bbl. sodium pyrophosphate	82	0.75	81	0.66
		98	0.65	101	0.52
		136	0.48	120	0.44
		178	0.36	178	0.33
3	2 lb. per bbl. quebracho	80	0.96	81	0.86
		101	0.77	100	0.70
		139	0.57	119	0.58
		182	0.47	180	0.39
4	2 lb. per bbl. each sodium pyrophosphate and quebracho	80	0.79	80	0.70
		103	0.64	100	0.57
		140	0.47	120	0.48
		178	0.37	180	0.33
4A	Same as No. 4			81[d]	0.64[d]
				100[d]	0.54[d]
				119[d]	0.45[d]
				180[d]	0.32[d]
5	5 lb. per bbl. each sodium pyrophosphate and quebracho	81	0.66	81	0.56
		100	0.55	101	0.45
		140	0.37	120	0.40
		178	0.31	180	0.29

[a] Mud density, 64.9 lb. per cu. ft. Filtrates obtained at 80°F. and 100 lb. per sq. in. Chlorides in filtrates, 7 grains per gallon (expressed as sodium chloride).

[b] Sample held 12 hr. at 180°F. before tests were made.

[c] Mud density, 85 lb. per cu. ft. Filtrates obtained at 80°F. and 100 lb. per sq. in. pressure. Chlorides in filtrate, 92 grains per gallon.

[d] Filtrate obtained at 180°F. and 1000 lb. per sq. in. pressure.

[e] Mud density, 69.6 lb. per cu. ft. Filtrates obtained at 80°F. and 100 lb. per sq. in. Chlorides in filtrate, 290 grains per gallon.

ANALYTICAL PROCEDURE

The muds were handled in the laboratory in the generally accepted manner.[13] The samples were strongly agitated by means of a Mixmaster type of stirrer just prior to the making of measurements. To expedite the tests, the samples were heated before agitation to the approximate temperature desired. In general, a mud was treated to the desired condition and was then tested at a series of temperatures. After agitation, the mud was placed in the cell and the upper electrode was inserted. At this point, great care was taken to see that all air was excluded from the cell. The cell was then brought to temperature equilibrium and a reading was obtained.

The process was repeated for other temperatures.

The filtrates were obtained from the filter press mentioned, and by proper control were collected at any temperature desired. The liquid thus accumulated was placed in the small cell, brought to temperature in the bath, and tested.

EXPERIMENTAL RESULTS

The experiments may be arranged in groups as tests to determine the effect upon the resistivity of the mud and filtrate by: (1) change of temperature, (2) chemical treatment, (3) increase in sodium chloride content, (4) addition of weighting material, and (5) contamination by cement and addition of counteracting reagents.

Effect of Temperature Change.—The experimental data showing the relation between resistivity and temperature change are presented in Tables 3, 4 and 5, together with the data on chemical treatment. The effect of temperature on the resistivities of the various muds is given graphically in Fig. 3. All five muds behaved in very much the same way and a change in temperature from 80°F. to 180°F. caused a decrease in resistivity to somewhat less than one half of the value at 80°F. This is better illustrated in Fig. 4, which shows the percentage reduction in the resistivity of the mud at 80°F. as a function of temperature. The percentage reduction in the resistivity with temperature is remarkably constant for the five muds.

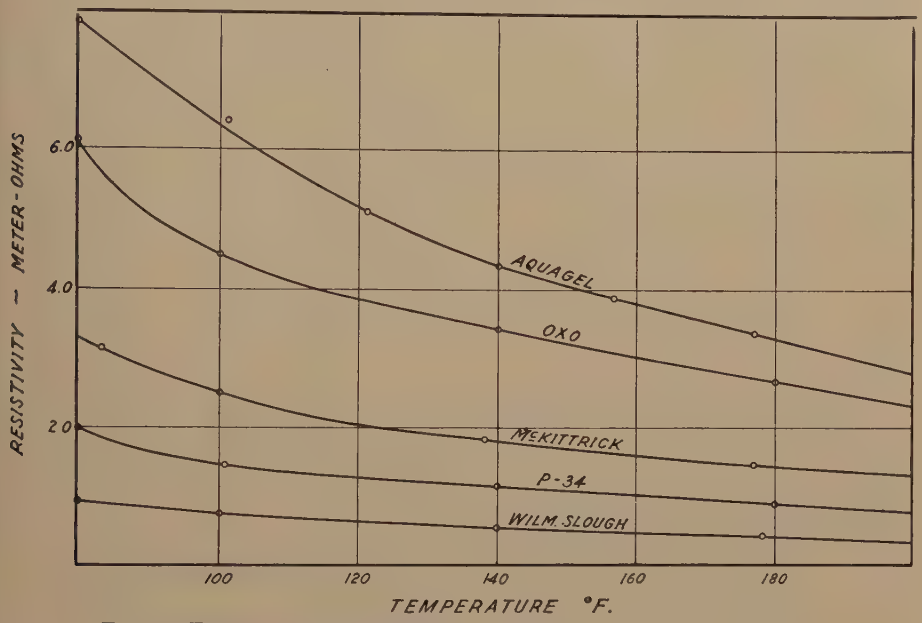

FIG. 3.—EFFECT OF TEMPERATURE UPON RESISTIVITY OF UNTREATED MUDS.

It was found that the filtrates behave in a manner very similar to that of the muds. In fact, with the exception of Aquagel and its filtrate, the figures for any particular mud and filtrate are almost identical. This is significant because it indicates that it can be assumed that if the properties of a given mud are known the properties of the filtrate penetrating the formation can be evaluated. In Fig. 5, the resistivity-temperature relations for a typical mud and for Aquagel are shown. The large deviation between the resistivities of Aquagel mud and filtrate are of interest.

TABLE 4.—*Effect of Chemical Treatment on Resistivity*

MCKITTRICK MUD AND FILTRATES[a]

Sample No.	Treatment	Mud			Filtrate		
		pH	Temperature, Deg. F.	Resistivity, Meter-ohms	pH	Temperature, Deg. F.	Resistivity, Meter-ohms
1	None	9.0	82 99 138 177	3.1 2.5 1.8 1.4	8.5	80 98 136 175	3.0 2.5 1.8 1.3
2	2 lb. per bbl. sodium pyrophosphate	9.8	83 99 136 177	1.6 1.3 0.94 0.74	9.4	86 102 142 174	1.3 1.1 0.79 0.64
3	2 lb. per bbl. quebracho	8.4	83 98 138 176	2.7 2.2 1.6 1.2		82 106 134 173	2.5 2.0 1.5 1.1
4	2 lb. per bbl. each sodium pyrophosphate	8.8	82 100 139 176	1.6 1.3 0.92 0.73	8.3	86 104 140 166	1.4 1.2 0.83 0.67
4A[b]	Same as No. 4		83 100	1.6 1.3		84 98	1.4 1.2
5	5 lb. per bbl. each sodium pyrophosphate and quebracho	9.0	83 98 138	0.94 0.79 0.58	8.5	83 106 133 171	0.72 0.55 0.43 0.34

[a] Mud density, 80 lb. per cu. ft. Filtrates obtained at 80°F. and 100 lb. per sq. in. pressure. Chlorides in filtrate, 14.4 grains per gal. (expressed as sodium chloride).

[b] Sample held 12 hr. at 180°F. before tests were made.

TABLE 5.—*Effect of Chemical Treatment on Resistivity*

OXO MUD AND FILTRATES[a]

Sample No.	Treatment	Mud			Filtrate	
		Filter Rate Diff. 5–15 Min., C.C.	Temperature, Deg. F.	Resistivity, Meter-ohms	Temperature, Deg. F.	Resistivity, Meter-ohms
1	None	5.2	80 100 140 180	6.1 4.5 3.4 2.7	81 100 140 180	5.8 4.6 3.2 2.4
1A[b]	None		177	2.7		
2	2 lb. per bbl. sodium pyrophosphate	4.0	80 100 140 180	4.3 3.2 2.4 1.9	80 99 140 180	5.3 4.2 2.9 2.1
3	2 lb. per bbl. quebracho	3.3	80 100 140 180	5.4 4.2 3.0 2.3	80 101 141 180	5.8 4.5 3.2 2.4
4	2 lb. per bbl. each sodium pyrophosphate and quebracho	3.0	80 100 140 180	3.8 2.9 2.1 1.7	80 100 140 179	4.6 3.7 2.6 2.2
4A	Same as No. 4				80 101 139 180	4.7[c] 3.7[c] 2.6[c] 1.9[c]
5	5 lb. per bbl. each sodium pyrophosphate and quebracho		80 100 141 180	1.8 1.3 0.93 0.74	80 100 140 180	2.5 2.1 1.4 1.4

[a] Mud density, 75.7 lb. per cu. ft. Filtrates obtained at 80°F. and 100 lb. per sq. in. Chlorides in filtrate, 15.4 grains per gallon.

[b] Sample held at 180°F. 12 hr. before tests were made.

[c] Filtrates obtained at 180°F. and 1000 lb. per sq. inch.

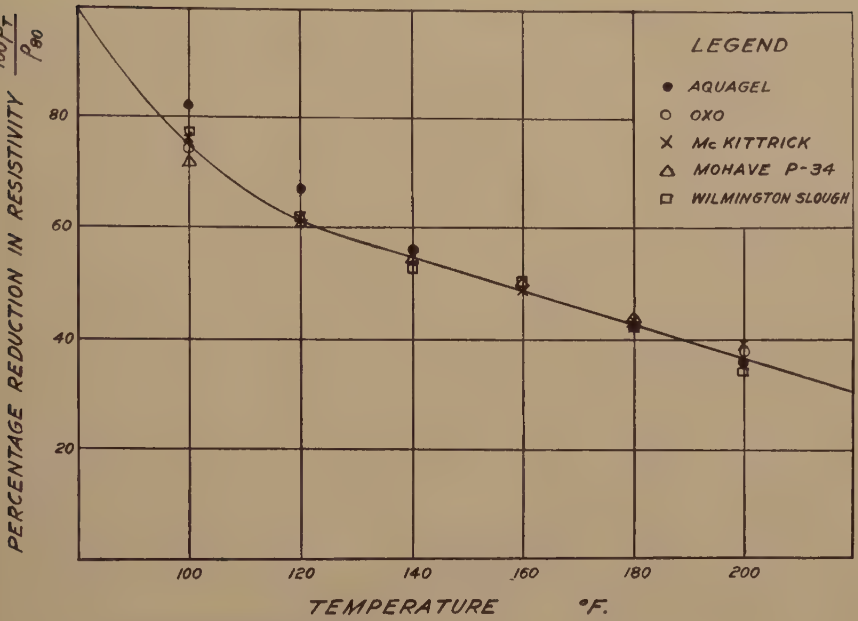

FIG. 4.—PERCENTAGE REDUCTION IN RESISTIVITY WITH TEMPERATURE.

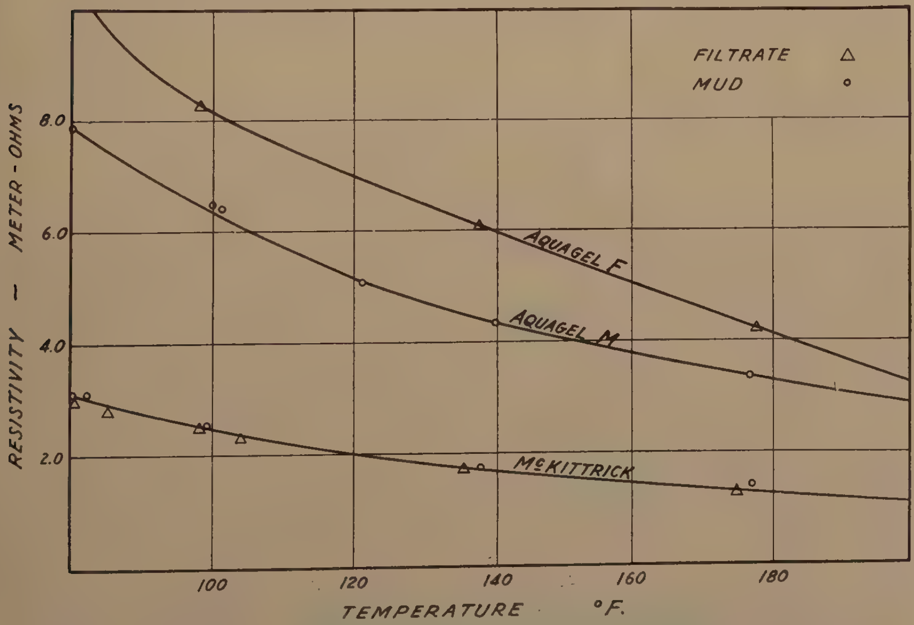

FIG. 5.—COMPARISON OF TEMPERATURE-RESISTIVITY RELATION FOR UNTREATED MUDS.

Aquagel is a product that is essentially composed of the one material, bentonite. When bentonite is dispersed in water, a very fine colloidal suspension is formed.

With a mud of this nature, the high resistivity of the filtrate in relation to that of the mud may result from the combination of several factors: (1) the concentration of salts in the filtrate is very low and with the relatively large amount of colloidal material in the mud, considerable absorption of inorganic ions must take place; which would tend to raise the resistivity of the filtrate relative to that of the mud; (2) the fact has been demonstrated that there exists an appreciable surface conductivity on solid particles in aqueous suspension, which becomes pronounced as the particle size is reduced; (3) there may also be an actual migration of the colloidal particles themselves—cataphoresis. Thus, a high colloid content would tend to reduce the resistivity of a suspension with respect to its filtrate.

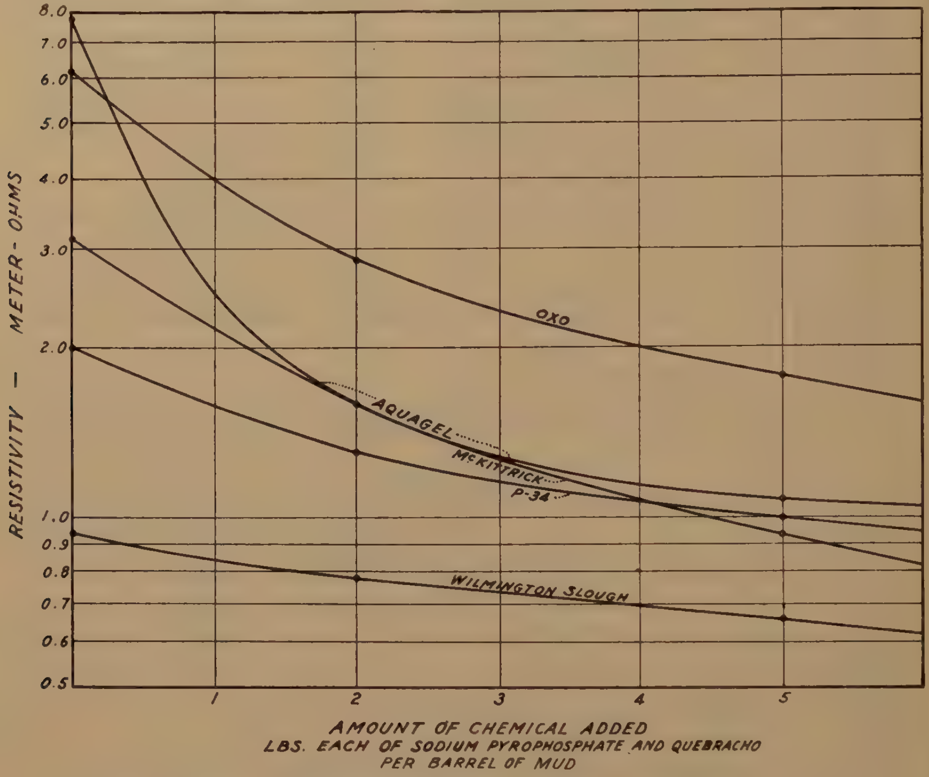

FIG. 6.—EFFECT OF CHEMICAL TREATMENT UPON MUD RESISTIVITY AT 80°F.

Changes in Resistivity Resulting from Chemical Treatment.—The results obtained from the chemical treatment of the muds are given in Tables 3 to 5. The change in mud resistivity with addition of chemical at 80°F. is shown in Fig. 6. The data represent changes resulting from the addition of equal amounts of each of sodium pyrophosphate and quebracho. Since the effect of the quebracho on the resistivity is virtually negligible, the data shown represent the effect of the sodium pyrophosphate. All of the muds show a decrease in resistivity with an increase in amount of chemical used. This is to be expected with such a strong electrolyte

TABLE 6.—*Effect of Sodium Chloride on Resistivity*

Sample No.	Treatment	Mud					Filtrates[a]		
		pH	Wt., Lb. per Cu. Ft.	Filter Rate 5–15 Min., C.C.	Temperature, Deg. F.	Resistivity, Meter-ohms	pH	Temperature, Deg. F.	Resistivity, Meter-ohms
	AQUAGEL MUD AND FILTRATES								
1	None	9.2		4.5	80	7.6	9.0	83	10.2
					100	6.5		98	8.2
					140	4.6		138	6.1
					180	3.5		178	4.2
2	0.15 lb. per bbl. NaCl (25.6 grains per gal. water in mud)	8.9		4.6	80	4.9	8.7	82	6.0
					100	4.0		103	4.9
					140	2.9		140	3.4
					180	2.2		180	2.7
3	0.30 lb. per bbl. NaCl (51.2 grains per gal. water in mud)	8.7		5.0	80	3.3	8.5	82	3.9
					104	2.6		100	3.2
					140	2.1		138	2.4
					180	1.6		176	1.8
4	0.58 lb. per bbl. NaCl (99 grains per gal. water in mud)	8.5		5.2	81	2.4	8.3	83	2.4
					102	1.9		102	2.0
					140	1.5		138	1.4
					180	1.1		174	1.1
5	1.17 lb. per bbl. NaCl (200 grains per gal. water in mud)	8.4		6.0	80	1.4	8.0	84	1.3
					100	1.2		99	1.2
					140	0.87		140	0.77
					180	0.68			
6	3.0 lb. per bbl. NaCl (512 grains per gal. water in mud)	8.4		6.8	81	0.71	7.8	83	0.56
					100	0.60		102	0.48
					140	0.48		140	0.35
	MCKITTRICK MUD AND FILTRATES								
1	None	9.0			80	3.1	8.5	85	2.8
					99	2.5		104	2.3
2	0.15 lb. per bbl. NaCl (30 grains per gal. water in mud)	9.8			80	2.5	9.6	82	2.1
					105	2.0		102	1.7
					138	1.5		139	1.2
					179	1.1		178	0.88
3	0.3 lb. per bbl. NaCl (60 grains per gal. water in mud)	9.4			81	2.2	9.0	84	1.8
					99	1.8		103	1.4
					138	1.3		135	0.98
					178	0.96		176	0.78
3A[b]	Same as No. 3				84	2.1		86	1.7
					101	1.7		100	1.5
4	0.58 lb. per bbl. NaCl (116 grains per gal. water in mud)	8.7			82	1.6	8.2	84	1.3
					100	1.3		104	1.1
					138	0.95		140	0.77
					176	0.75		178	0.57
5	1.17 lb. per bbl. NaCl (234 grains per gal. water in mud)	9.0			83	1.1	8.4	86	0.83
					100	0.94		103	0.71
					138	0.70		140	0.51
					180	0.57			
	OXO MUD AND FILTRATES								
1	None	8.7	75.7	5.3	82	6.0	8.4	82	5.7
					101	4.7		105	4.4
					140	3.4		140	3.2
					180	2.6		180	2.4
2	0.15 lb. per bbl. NaCl (28.6 grains per gal. water in mud)	8.7	87.3	6.0	83	3.8	8.6	80	3.4
					100	3.2		100	3.0
					143	2.4		138	2.1
					181	1.9		180	1.6
3	0.30 lb. per bbl. NaCl (57.3 grains per gal. water in mud)	8.7	86.5	7.2	83	3.0	7.5	84	2.8
					98	2.7		102	2.2
					136	1.9		143	1.3
					180	1.5		176	1.2
4	0.58 lb. per bbl. NaCl (111 grains per gal. water in mud)	8.5	84.8	7.8	83	2.2	8.5	84	1.9
					101	1.9		104	1.6
					136	1.4		140	1.2
					180	1.1		179	0.86
5	1.17 lb. per bbl. NaCl (224 grains per gal. water in mud)	8.3	83.2	8.0	81	1.4	8.6	84	1.2
					98	1.2		100	0.96
					137	0.85		139	0.70
					180	0.65		179	0.53
6	3.01 lb. per bbl. NaCl (575 grains per gal. water in mud)	8.1	81.1	11.5	80	0.70	8.1	84	0.55
					99	0.59		98	0.47
					138	0.45		142	0.35
					179	0.35		178	0.30

[a] Filtrates obtained at 80°F. and 100 lb. per sq. in. pressure.

[b] Sample held 12 hr. at 180°F. before tests were made.

as sodium pyrophosphate. While all of the muds tested show this inverse relation between resistivity and chemical treatment, there is no uniformity of manner in which they respond. Thus, it would not be possible to infer reliably the response of another mud from the reaction of the muds tested, as might be done with the resistivity-temperature relation.

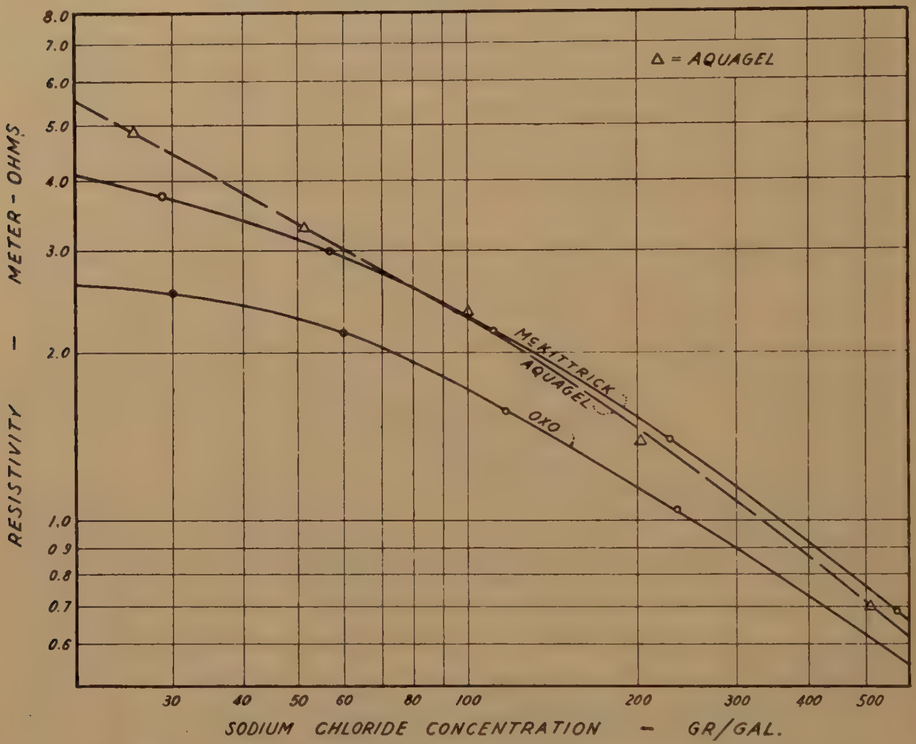

FIG. 7.—EFFECT OF SODIUM CHLORIDE UPON MUD RESISTIVITY AT 80°F.

As indicated by the data, the behavior of the filtrate is even more nonuniform than that of the corresponding muds. Although there is a general decrease in resistivity with increase in amount of chemical used, the rate of change of this function varies exceedingly for the different filtrates. Just how this variation is related to what must be an extremely complex condition, the state of the colloidal system at the time the filtrate was extracted, has not been determined.

Effect of Sodium Chloride.—In the drilling of a well to a deep producing interval, numerous zones bearing waters high in salt concentration are frequently encountered before the desired oil zone is reached. Thus, in the drilling of these intervals, the mud sometimes undergoes a change in salt concentration. Almost universally, the sodium chloride of these waters far exceeds in quantity the other salts present. Because of this great preponderance of sodium chloride, and because native muds differ so markedly in their sodium chloride contents, a series of tests was made to establish the effect of this salt upon the resistivities of Aquagel, McKittrick and Oxo muds and their filtrates. The experimental results are given in Table 6. The change in resistivity with change in sodium chloride concentration at a temperature of 80°F. is shown in Fig. 7.

A marked decrease in resistivity with increase in sodium chloride occurs. All three of the muds thus tested were low originally in sodium chloride content, as was noted in Table 1. The fact is of considerable significance that, when enough salt is added to any of these muds to cause its sodium chloride content to approach that of either of the other two more highly saline muds, the resistivity approaches closely the resistivity of the more saline muds. Thus, it becomes apparent, at least for the cases studied, that the resistivity of an untreated native mud is largely a function of its salinity.

The change in filtrate resistivity with salinity is very similar to that of the corresponding muds but it must be noted that, at the salinities higher than 100 grains per gallon, the filtrate resistivities decrease at a slightly greater rate with increased sodium chloride concentration than do those of the muds themselves.

Changes in Mud Resistivity Resulting from Addition of Weight Material.—The occurrence of quantities of gas or excessive pressure is encountered frequently during the drilling of a well. Under these circumstances, the addition of some heavy inert material to the mud to increase its density is common. The materials used most frequently at present in California are Baroid (essentially barium sulphate) and limestone. The addition of either one of these to the mud tested resulted in a slight but steady increase in resistivity. The data indicate that the change in resistivity with increase in amount of heavy material is almost linear. The complete data pertaining to the addition of weighting material are given in Table 7.

Effect of Cement and Sodium Bicarbonate upon Resistivity.—The circumstances of present-day well-completion practice often result in the contamination of drilling mud by cement shortly before an electric log is made of the interval to be produced. Cement generally makes very important changes in the performance characteristics of muds. Therefore, it is common practice to treat cement-contaminated mud with sodium bicarbonate to restore it, as nearly as possible, to its original condition. The effect of both cement and sodium bicarbonate upon the resistivity of McKittrick mud was studied. The results of the investigation are presented in Table 8. Both Portland cement and sodium bicarbonate produce a decrease in mud resistivity. The proportions of cement and reagent used for the treatment of the mud during these experiments are approximately those encountered in ordinary field operations.

TABLE 7.—*Effect of Baroid and Limestone on Resistivity of McKittrick Mud*

Treatment	Weight, Lb. per Cu. Ft.	Temperature, Deg. F.	Resistivity, Meter-ohms
None	80	84	3.1
		100	2.6
		138	1.9
		172	1.5
56.2 lb. per bbl. $CaCO_3$	85	83	3.3
		100	2.8
		138	2.1
		177	1.6
197 lb. per bbl. $CaCO_3$	95	81	4.2
		100	3.5
		136	2.5
		175	[illegible].0
40.2 lb. per bbl. $BaSO_4$	85	82	3.3
		100	2.7
		140	2.0
		176	1.6
127 lb. per bbl. $BaSO_4$	95	85	3.7
		100	3.2
		130	2.5
		162	2.0

Effect of Mud Resistivity on Electric Logs.—In an effort to establish the fact that the logs are influenced appreciably by the mud resistivity, a study was made of a number of logs taken in each of two fields where conditions were rather well known. In each case, a rather thick body (about 15 ft.) of sand that could be readily traced from log to log throughout the field was measured. The amplitude of the curve from the average shale line at the portion of the log studied was determined for both the normal resistivity (shallow pene-

TABLE 8.—*Effect of Portland Cement on Resistivity of McKittrick Mud and Filtrates*

Treatment	Mud			Filtrate[a]	
	pH	Temperature, Deg. F.	Resistivity, Meter-ohms	Temperature, Deg. F.	Resistivity, Meter-ohms
None	9.0	81	3.2	85	3.1
		135	2.0	151	1.8
½ lb. per bbl. cement	10.1	82	3.0	86	3.2
		139	1.9	135	2.1
3 lb. per bbl. cement	11.0	84	2.2	88	2.0
		135	1.3	136	1.3
½ lb. per bbl. each cement and $NaHCO_3$	9.5	80	2.7	81	2.9
		141	1.6	138	1.6
3 lb. per bbl. each cement and $NaHCO_3$.	10.5	82	1.3	82	0.98
		141	0.77	138	0.57

[a] Filtrates obtained at 80°F. and 100 lb. per sq. in.

tration) curve and the natural potential curve. These values were plotted against the resistivity of the mud present in the well bore at the time of logging. The resistivities were reduced to a common temperature of 80°F. by means of the data reported above. A relationship that established the trend of the change in amplitude with mud resistivity was obtained by the method of least squares. The graph resulting from the plotting of the deflection of the normal curve as a function of mud resistivity for the same section of the logs of 25 wells in a given field is shown in Fig. 8. Similar data for wells in another field are presented in Fig. 9. The deflection was measured by ascertaining the average position of the curve opposite the sand interval relative to a line drawn through the average shale position. It is evident from the spread of the data that many factors other than mud resistivity, which could not readily be evaluated, affect the amplitude of the logs. However, that there is a definite relation between mud resistivity and the amplitude is evidenced by the trend.

It was possible, during the study, to obtain data on two wells in which duplicate logs had been run for conditions of different mud resistivities. These showed rather markedly that the log is to an appreciable measure a function of the mud resistivity. These data are represented by the curves for well A and well B on Fig. 8. Data of a similar nature have been presented by M. C. Bowsky,[14] showing that for a well in Louisiana in which five logs were made over a two-weeks period the mud resistivity was successively 3.15, 2.44, 1.79, 0.90, 0.34 meter-ohms at 106°F. Bowsky found that when the same section was compared on each log, the relative intensities of the normal curve were 8.0, 4.0, 2.45, 1.4 and 1.0. This represents an eightfold change in the amplitude of the normal curve for the range in mud resistivity encountered. In like manner, Bowsky found that the natural or self-potential curve was three times as sensitive in the mud having the highest resistivity as it was for the mud with lower resistivity.

In keeping with the findings of Mr. Bowsky, an analysis of the same section of 25 logs taken in the same field showed an average variation in the amplitude of the self-potential curve from 10 to 35 millivolts for a sixteen-fold change in mud resistivity, with as high as a two and four-tenths fold change per meter-ohm in amplitude for the change in mud resistivity encountered in an individual well with duplicate logs. These data are presented in Fig. 10. The average curve was obtained by the method of least squares.

As a striking example of the magnitude of the effect that mud resistivity can produce upon a log, there is shown in Fig. 11 a portion of a curve from a well logged under widely differing mud conditions. In the case illustrated, the well was drilled with a mud for which the make-up water was taken from the producing formation of an adjacent well. When the log was run in this highly saline mud, the resistivity of which was 0.8 meter-ohm at surface temperature, no deflection of the self-potential curve was obtained. The following day the mud was replaced by mud having a resistivity of 2.0 meter-ohms and a second log was run. As can be seen in the right-hand portion of the illustration, a very much improved log was obtained.

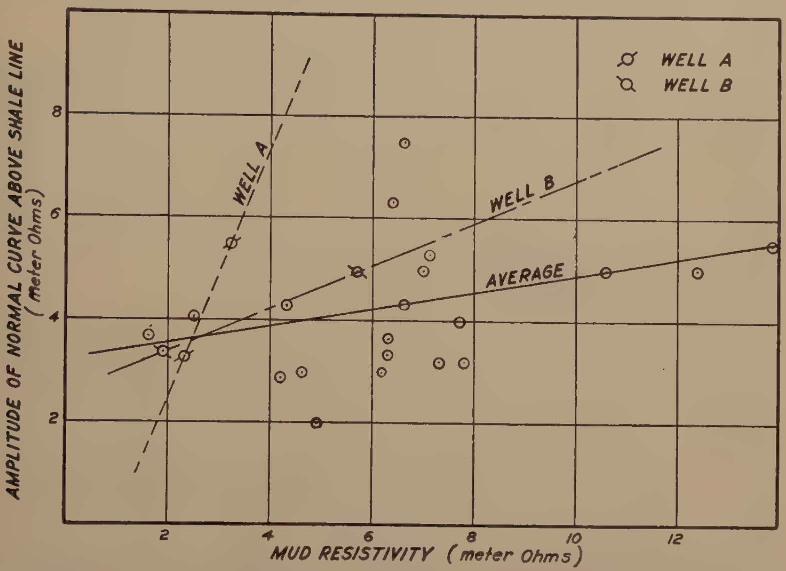

Fig. 8.—Effect of mud resistivity on amplitude of normal curve above shale line.

Application of Results of This Investigation to Field Practice

That the resistivity of drillling muds, and hence the effect produced by the mud upon electric logs, are profoundly altered by various treatments given to drilling fluids under conditions existing in modern field practice, has been amply demonstrated in the foregoing pages. The fact is emphasized that the data presented herein do not by any means provide all of the information necessary for the complete interpretation of electric logs. Rather, they represent the material necessary to partly evaluate only one of the many factors that influence the logs. Petroleum technologists for some time have been gathering material relative to many of the other factors such as porosity, permeability, fluid content, and other formation characteristics that influence electric logs. Given sufficient information about each factor, it should be possible to interpret properly the electrical record, not only in terms of rock type but also in terms of the content of its interstices. It is believed, therefore, that the proper interpretation of electric logs will be enhanced by a knowledge of such data as have been obtained in this investigation.

At present no provision is made in the routine field testing of drilling fluid to determine the resistivities of the mud used. Furthermore, the results of the tests listed above indicate fairly conclusively that the only reliable method for predicting and interpreting the effect of drilling muds and their filtrates on electric logs is to make, among other things, resistivity measurements on muds actually used in drilling wells and apply temperature corrections from data such as those reported in this investigation.

The apparatus used for these determinations, as stated earlier, is strong, inexpensive, and simple to operate. Furthermore, the time necessary for making a test is only three or four minutes. It is believed, therefore, that the results to be obtained from the routine use of such apparatus will fully justify the necessary cost in increased value obtained from electric logs. Such a device has been used successfully by the Union Oil Company of California for more than a year, in the routine analysis of drilling muds.

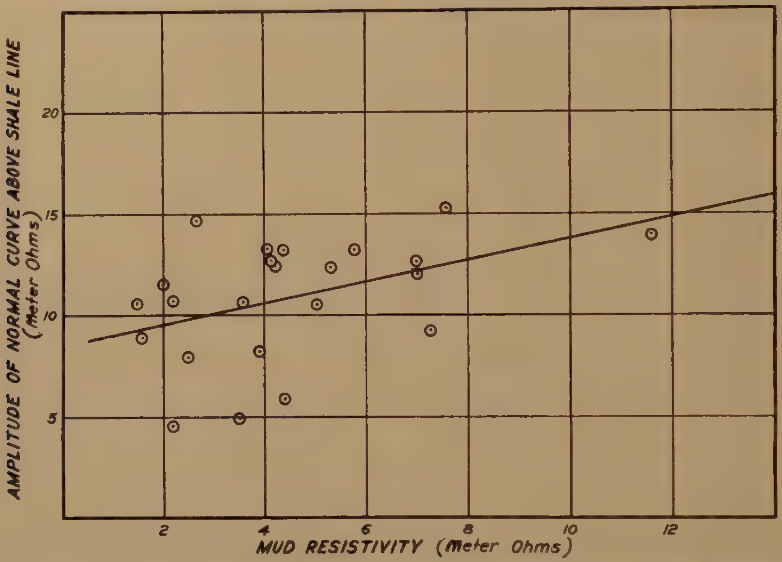

FIG. 9.—EFFECT OF MUD RESISTIVITY ON AMPLITUDE OF NORMAL CURVE ABOVE SHALE LINE.

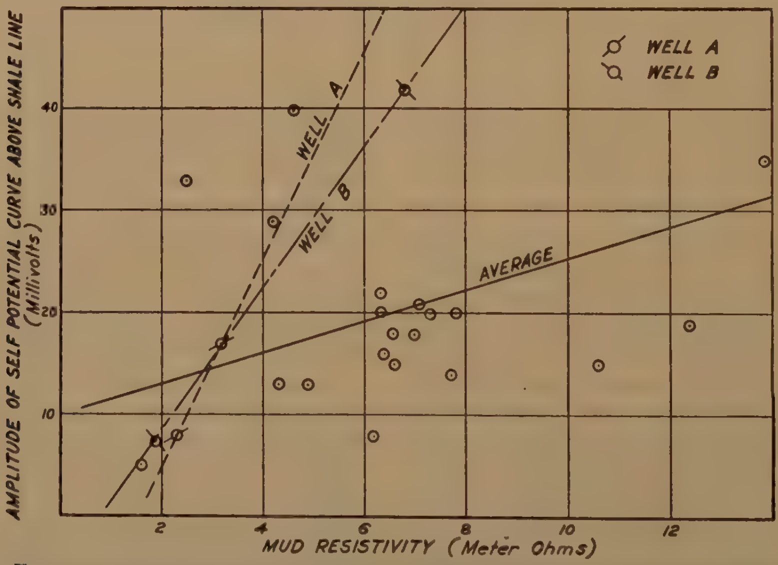

FIG. 10.—EFFECT OF MUD RESISTIVITY ON AMPLITUDE OF SELF-POTENTIAL CURVE ABOVE SHALE LINE.

The studies made upon the logs indicate definitely that all the readily available information that might have a bearing upon the interpretation of logs should be obtained with the log at the time of its taking. For example, many of the logs available for the studies mentioned herein could not be used because no temperature value was given for the mud-resistivity measurement. Even today, many logs lack this essential piece of information.

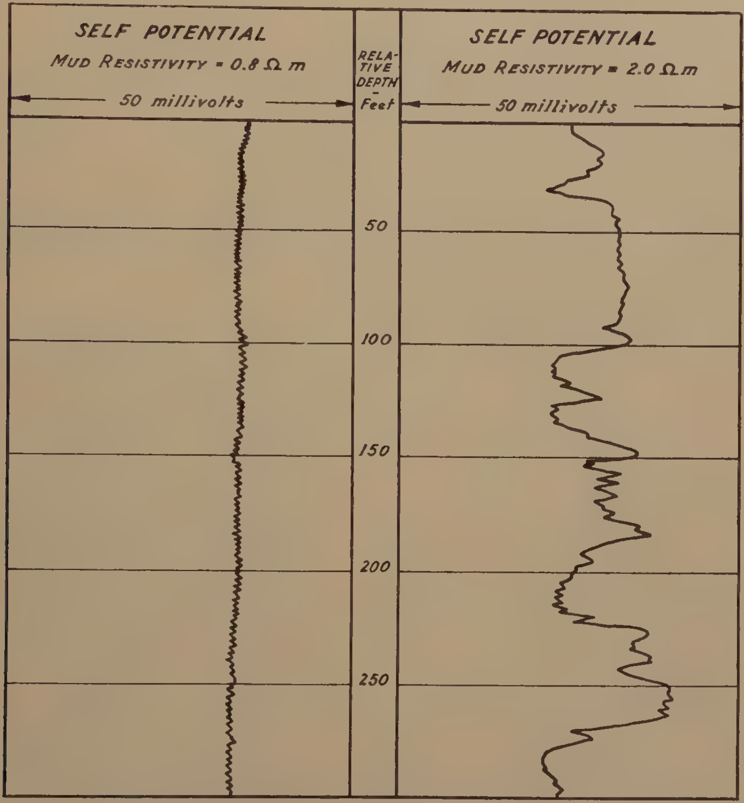

FIG. 11.—EFFECT OF MUD UPON THE SELF-POTENTIAL CURVE.

If the logs are not to be used just as a means of attacking today's problems, but as a foundation for greater utilization of tomorrow's logs, a concerted effort should be made throughout the industry to associate with the logs being made today the information that may later prove to be the key to the solution of the problem, even though such information may have little present-day application.

SUMMARY AND CONCLUSIONS

The relation between the properties of electric logs and the fluid used in drilling a well has been briefly discussed. The fact that the resistivity of the drilling mud and its filtrate can appreciably affect such logs has been shown.

Apparatus was designed and a procedure established to determine the effect of various factors on the resistivity of drilling mud. Five muds commonly employed in California were tested and the following observations were made:

1. The effect of raising the temperature from 80°F. to 180°F. is to decrease the resistivity of the mud or filtrate approximately 50 per cent. This appears to be roughly true for chemically treated muds as well as native muds.

2. The resistivity of the mud in most cases closely approximates that of its filtrate; therefore, the determination of the resistivity of a mud used in a well usually

will provide a reliable picture of the resistivity of the filtrate that will be forced into the formation from the mud.

3. The change in the resistivities of muds caused by the addition of chemical is not the same function of the amount of chemical added for each mud. Electrolytes used in mud treatment lower resistivity and, therefore, tend to decrease the sensitivity of electric logs. Nonelectrolytes, such as quebracho, have little effect.

4. The effect produced by increased sodium chloride content is to reduce markedly the resistivity of the mud and its filtrate. The fact was noted that when enough sodium chloride was added to a mud low in salt content so that its resulting salinity approached that of a more saline native mud, the resistivity of the mud so treated approached very closely that of the saltier mud. This indicates that a knowledge of the chloride content of a native mud will often enable the rough evaluation of its resistivity.

5. Weighting materials, such as Baroid and limestone, tend to increase the resistivity of drilling mud.

6. Cement and sodium bicarbonate used in treating the mud for cement contamination cause reduced mud resistivity.

7. Statistical data, and a few individual tests obtained under field conditions, amply demonstrate the importance of the mud resistivity in its affect on electric logging, and point to the need for further control in the field.

The fact is recognized that the material presented herein represents only a reconnaissance of the problem investigated, and that further and more detailed study could profitably be made. It is hoped, therefore, that this brief study will stimulate further investigation.

ACKNOWLEDGMENT

The writers wish to gratefully acknowledge their indebtedness to Mr. Howard C. Pyle and Mr. P. H. Jones for many helpful suggestions, to Messrs. Robert Rose and C. F. Bowden, who performed a number of the experiments, and to the Union Oil Company of California for its release of the data presented.

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Chapter III. Petroleum Economics

Some Factors in the Economics of Recycling

By Emby Kaye*

(New York Meeting, February 1941)

It is the purpose of this paper to outline briefly some of the considerations that enter into the economics of so-called recycling, the generic designation of the relatively recently developed process by which a condensate† is separated from gas-distillate gas at high pressure and the residual gas returned to the reservoir. This subject necessarily embraces not only a discussion of factors that should be considered in projecting a recycling operation, such as estimating reserves, investment and operating costs, but also a comparison of condensate with other types of petroleum. The place of condensate in its relation to the total supply of crude oil is pointed out as well as certain logical methods of product disposal. The cost of drilling wells and lease maintenance is not pertinent to this discussion because income and revenue are in this paper confined to that retained by the plant or plant operator for supplying processing facilities for the gas.

Before the development of recycling a great many gas-distillate gas fields in Louisiana and Texas provided no income to their owners. When gas was sold from these reservoirs it was accompanied by irretrievable losses of condensate in the formation. The understanding of the function of retrograde condensation resulted in the introduction of a new commercial petroleum recovery process for these hitherto unexploited fields and now permits the conditioning of this type of wet gas field for the sale of dry gas therefrom without waste.

Some Economic Factors

The study of a gas-distillate field for possible exploitation necessarily involves the critical appraisal of a number of elements, chief of which will be discussed here: (1) estimate of distillate in place, (2) estimate of distillate that can be brought to the surface, (3) available market, (4) costs.

The considerations affecting the estimating of distillate reserves in place are in the main subject to the same errors as are involved in determining dry gas reserves. Determinable data including acreage, sand thickness, reservoir pressure, reservoir temperature, porosity and connate water provide the basis for calculating the volume of gas in place. Ample allowance must be made for connate water, which may occupy from 20 to 35 per cent of the pore space of the sand. The factor of supercompressibility is to a considerable extent nullified by the reservoir temperature. It has been considered well advised to allow this factor to serve as a cushion. With the gas reserves calculated, it remains only to assay the distillate content of the gas.

Those familiar with the handling of "wet" gas at high pressure readily appreciate the variables in sampling gas from

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† Distillate and condensate are used interchangeably in the industry and will be so used here. The writer likes to refer to distillate in the reservoir and condensate when it has been reduced to a liquid on the surface.

distillate wells that may make the determinations of little value. First and foremost is, of course, the necessity for getting the well stabilized before the gas is sampled. The well should be allowed to flow at a rate approximately that at which it would flow if produced as part of the recycling project, and it should flow until the temperature at the well head ceases to change. The condensate accumulated in the separator is measured against the separated gas. A portion of this gas is passed through a charcoal tube or collected for laboratory analysis. The total gas-free condensate is then applied to the volume of gas passed through the separator during the test. A detailed method of sampling appears in the Appendix of this paper.

No one determination for a recycling project is as difficult to make, and is as uncertain when made, as is the estimate of what portion of the wet gas reserves may be brought to the surface for processing there, before dilution or mixing with dry gas makes the operation uneconomical. Earlier concepts of a 90 per cent or even an 85 per cent recovery factor must be revised downward save where the formations are extraordinarily uniform and regular and the field long and narrow—most unusual cases.

It is believed that essentially the injected gas travels en masse. Swearingen[1] has indicated graphically, by the use of electrical models, the direction of flow caused by the displacement of the wet gas by the injected dry gas. This work is substantially the same as earlier analyses of secondary water floods by Wyckoff.[2] In Swearingen models, a layer of electrolyte whose ion content represents the gas content of the sand responds to potential differences in exactly the same manner in which gas in the formation responds to pressure differences. His now familiar work provides a means for determining constants representing areas displaced by dry gas for different types of well patterns. In light of this work, to a great extent confirmed by the performance record of several dozen output wells that have become dry or partly dry since the original paper was written, most of the projects will do well to show ultimately a recovery factor of 60 to 70 per cent. But even the further proving of the Swearingen method will leave much to be desired in accurately forecasting the recovery factor in the average field. Shale breaks, radical variations in permeability and porosity and sharp differences in sand thickness doubtless will vary the actual shape of the gas travel as against the pattern on the electrical model. Nevertheless, the method is useful as a check and is particularly helpful in suggesting the most desirable well pattern and the location of input wells to the end that the highest production of virgin gas may be obtained.

Too much emphasis cannot be placed upon the necessity for calculating reserves conservatively. If the geologist in reading the Schlumberger calls a sand from the beginning of the kick to the end and includes every foot of even the tightest sand, there is likely to be an overestimate of reserves in place and this will be compounded when the recoverable reserves are calculated.

The efficiency of aboveground extraction of distillate may be discounted. This is a function of plant design and operating pressure and may vary from 90 to 99+ per cent of the pentanes and heavier and up to 80 per cent of the butane. But there is another variable in estimating the condensate-recovery factor. Whether the ultimate distillate recovery will be in proportion to the wet gas recovered and the original liquid content of the gas, will depend upon whether or not substantially original reservoir pressures are to be maintained until the recycling project has been completed. Condensate is a vapor above the dew point. If the pressure is reduced in the reservoir by withdrawal of gas to a point below the dew point, a part of the condensate will be liquefied and remain lost in the sand. This pressure drop can be calculated and the diminution in content accurately determined. Several examples of such losses may be cited.

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[1] References are at the end of the paper.

Patten[3] has shown that the drop in pressure at La Blanca from 4900 to 3800 lb. resulted in a diminution of the distillate content of the gas from 18 to 9 bbl. per million cubic feet, or 50 per cent of the original reserves. The rest was condensed in the sand by retrograde condensation and made unrecoverable. Incidentally, a further drop in reservoir pressure to 2180 lb. reduced the condensate content to 2.6 bbl. per million cubic feet of gas. On the basis of total reserves of one trillion, three hundred billion cubic feet of gas estimated for the gas cap of the Turner Valley field the naphtha content in the gas has dropped from 1.5 to 0.37 gal. per 1000 cu. ft. of gas as a result of the loss of reservoir pressure. By assuming an average yield of 0.9 gal. and a loss of 0.56 gal. per 1000 cu. ft. of gas, we arrive at a loss of 728 million gallons, or over 17 million three hundred thousand barrels worth possibly thirty-five million dollars ($35,000,000) in that area.

As has been indicated in the preceding paragraph, present recovery methods are highly efficient in extraction and are practiced without excessive gas loss or reservoir-pressure depletion except where the gas is exceedingly rich. Extraction pressures up to approximately 2000 lb. per sq. in. have been observed and higher pressures are indicated. Three primary methods are used and have been extensively described in the literature.[4–8] They may be differentiated as follows: (1) mechanical refrigeration and retrograde process, (2) regenerative cooling and retrograde method, and (3) absorption processes operating at high pressures.

In some plants combinations of these methods have been employed. Each method has its place or may be preferred by a particular designer for a specific situation. The character of the gas or the nature of the product desired, or both, may often control the choice. Whatever the separation process, the processed gas is compressed and returned to the formation.

Plant Size and Investment

Many considerations enter into the size of the plant to be built. They are important in the order listed: (1) extent of reserves, (2) gas market, (3) cost of production and (4) condensate market. If the reserves are exceedingly large, a size of plant that will cost the lowest per unit of capacity and will be lowest in the cost of production should be considered. These cost factors indicate a size of the order of seventy-five million cubic feet per day. Beyond this the per unit cost does not decrease appreciably. (See Appendix, Costs.)

The smallest plant of economic size must absorb the cost of camp, preparation of plant site, minimum loading facilities, minimum power plant, lighting system, instrumentation and controls, certain buildings, water facilities, sewage, fence, laboratory, office, dwellings, minimum storage, repair facilities, warehouse, ethyl blending plant (if motor fuels are to be produced), transportation facilities and gas-gathering system, and other items. These facilities may vary in cost according to the location of the plant and the taste of the operator. As little as $75,000 and as much as $150,000 may be expended for them for a plant having a capacity of twenty-five million cubic feet, which is considered as small a plant as is feasible for processing gas of approximately one gallon content per 1000 cu. ft. At least this amount can be saved by doubling the plant capacity. There is obviously not the same saving in increasing the projected size from fifty million to seventy five million or one hundred million cubic feet. The major saving is in the initial increase from a nominal size. Other items of the plant, such as vessels and exchangers, tend to increase in cost per unit of volume after a certain capacity has been reached. Increases beyond this, then, represent unchanging unit costs. Similarly, the cost of compression machinery does not decrease after the economic size of compressor has been reached.

Plants built to date have cost from $8 to $13 per 1000 cu. ft., or from $8 to $13 per gallon of condensate. Under normal conditions, $11 per 1000 cu. ft. should, with wells of average size, cover the ordinary cost of an efficiently operable plant of fifty million cubic feet capacity, designed for a field having a reservoir pressure of 3000 pounds.

Assuming a reserve of three hundred billion cubic feet of gas of one gallon per thousand content, it would be difficult to find any justification from a profit standpoint alone for a 7-year exhaustion of the recoverable reserves with a plant of seventy-five million cubic feet capacity against a 10-year exhaustion of the reserves with a plant of fifty million cubic feet capacity. The smaller plant, within a safe economic range, will, by reason of the lower investment, reduce the hazard against premature drying up of the wells, and after the payout will permit a longer profitable operating life for the project if wet gas continues to be produced for the full projected life of the plant. A plant should be projected to pay out the investment in from 2½ to 3½ years and allow at least an additional 5 years of profitable operation. There are situations, with very large reserves, where, of course, longer payouts are justified. There are also exceptional cases where more rapid exhaustion of reserves is warranted. One such case will be illustrated.

The reservoir from which gas is taken and a maximum not returned thereto, by reason either of gas lost with production of crude oil from the same or a mechanically connected sand, or by disposal as fuel, requires exceptional treatment. Where there is a market for gas, such gas is with few exceptions worth considerably more than the condensate content of the gas where the content is of the order of one gallon per 1000 cu. ft. of gas. The diminution in condensate content in the gas, which would result from the drop in pressure and consequent retrograde condensation in the reservoir caused by these permanent gas withdrawals, therefore, justifies as rapid an exhaustion of the condensate by recycling as the recoverable reserves and the cost of the plant will permit. But there is no compromising with the principle that gas should not be permanently removed from a reservoir concomitant with recycling if a loss in ultimate production of distillate is to be avoided. On the contrary, there is at least one case where gas is being taken from a reservoir although the writer has strongly urged the wisdom of borrowing gas from a utility company to make up for the high shrinkage due to the condensation of the heavier fractions and solution gas withdrawn with the rich condensate. The drop of reservoir pressure in this field is translating itself increasingly into a permanent and absolute loss of condensate. Withholding gas sales until the condensate is recovered from the reservoir does not mean that the income from gas sales would be lost. It would only be deferred, and when the gas was sold, in this particular case, it would probably be sold at a higher price unless important gas reserves were discovered in the general area.

Operating Cost

Costs per unit of capacity vary with the reservoir pressure, the condensate content of the gas, extraction efficiency embraced in the design, gas capacity of the wells and the character of the condensate. Cost of production per gallon is affected by substantially the same factors, particularly by the richness of the gas and by the percentage of production or value thereof paid to the producer of the gas or allocated to the lease from which it is produced. Of course, the realizable value also affects the cost. The direct operating costs per gallon, exclusive of raw material, are comparable to costs of manufacturing natural gasoline in plants of equal capacity. Depreciation ought to be calculated on a short-term basis because of the uncertainties attending the determination of the life of the project. Gas costs generally are higher than those in the natural gasoline industry because the percentage of the value of the product paid to the gas producer or allocated to the lease is higher—as much as three to four times in the case of the leaner gases. Unlike the schedules in the natural gasoline industry, the producer's share in the realization is fixed as a percentage thereof without regard to the condensate content or the price received for the product. The marked difference in price is unwarranted and reflects the opinion of some of the earlier bidders for gas, who looked at recycling as a bonanza.

Cost figures shown in the Appendix for plants of several sizes range from $0.0031 to $0.0054 per gallon exclusive of depreciation and raw material. With these items included the costs run from $0.0201 to $0.0246 per gallon when the condensate is worth $0.025 per gallon.

CONDENSATE VS. NATURAL GASOLINE AND REFINERY GASOLINE

A brief explanation might be made here regarding the difference between the characteristics and the value of condensate, natural gasoline and refinery gasoline. This comparison can be facilitated by setting out the characteristics of a number of typical condensates (Table 1). It should be noted that up to this time only one field has been observed to produce a condensate of type 3 (Table 1), which so nearly approximates the more volatile grades of natural gasoline. Typical condensates are composed essentially of hydrocarbons boiling within the motor-fuel range with varying percentages of natural gasoline and kerosene distillate. Condensates 1, 2 and 4 as analyzed here do not include the natural gasoline fractions, which would represent from 10 to 20 per cent of the total recoverable condensables in the gas. A composite condensate including the recovered natural gasoline would be composed of approximately 10 per cent natural gasoline, 75 per cent motor fuel or naphtha and 15 per cent kerosene distillate.

TABLE 1.—*Characteristics of Typical Condensates*

	1	2	3	4
Gravity	64.1	55.2	83.0	61.7
Doctor	Negative	Negative	Negative	Negative
Color	Water White	22	30	20
Odor	Sweet	Sweet	Sweet	Sweet
Sulphur, per cent	0.01	0.00	0.00	0.01
Copper dish	Negative	Negative	Negative	Negative
	Degrees Fahrenheit			
1 boiling point	96	94	66	95
10 per cent	144	166	81	156
20 per cent	179	192	92	181
30 per cent	215	217	106	200
40 per cent	248	237	124	220
50 per cent	282	260	145	238
60 per cent	321	294	170	244
70 per cent	374	336	199	291
80 per cent	441	400	234	330
90 per cent	544	490	293	408
End point	606	568	385	498
Recovery, per cent	94	97	95	96.5
Residue, per cent	3	1.5	1	1.5
Loss, per cent	3	1.5	4.0	2.0

These data indicate that condensate is not a natural gasoline. Natural gasoline is utilized by the refiner, when he does not use it simply because it is a cheap source of motor fuel, chiefly for its volatility characteristics. To an extent it is used to improve the antiknock rating of refinery motor fuels but the continuing skyrocketing of the octane number to a point well beyond the octane rating of the more stable grades of natural gasoline has measurably affected the use of naturals for this purpose. It has created a selective market and emphasized the demand for naturals of highest antiknock values. Condensates, on the other hand, are neither particularly volatile nor high in antiknock. Motor fuels distilled from them to 400 end point show octane numbers from 50 to 64, the preponderance falling in the 50–60 range.

TABLE 2.—*Evaluation of Products*

	End Products	Gallons	74 Octane (Less Lead Cost)		Realizable Value
			Tetraethyl Lead, C.c.	Assumed Value	
Condensate.......	10 per cent natural	4.2		0.025	$0.10500
	10 per cent light gasoline	4.2	0.6	0.04344	0.18244
	50 per cent cracked gasoline	21.0	0.6	0.04344	0.91284
	15 per cent distillate	6.3		0.025	0.22050
	13 per cent gas	5.46		0.015	0.08190
	2 per cent loss	0.84			
		100.00 per cent			$1.50
Crude oil.........	20 per cent S.R. gasoline	8.4	2.3	0.03902	0.3277
	10 per cent re-formed gasoline	4.2	0.6	0.04344	0.1824
	30 per cent cracked gasoline	12.6	0.6+	0.043	0.5418
	10 per cent distillate gasoline	4.2		0.035	0.1470
	18 per cent fuel oil	7.56		0.015	0.1134
	10 per cent gas	4.20		0.015	0.0630
	2 per cent loss	0.84			
		100.00 per cent			$1.375
Value of condensate products over products from barrels of crude............................					$0.125

PRODUCT EVALUATION AND DISPOSAL

Condensates more nearly approximate the products of simple distillation of crude oil, through the lighter burning oils, with 75 per cent or more falling into the gasoline-naphtha boiling range. Any comparative evaluation of condensate with other products therefore should be with crude oil, which it directly displaces as a source of motor fuel. Estimated realizations from a typical crude oil of 40° A.P.I. gravity and from a representative condensate converted to marketable products are here set down for ready comparison on a per barrel basis, when the 74 octane gasoline is worth $0.045 a gallon. Note that the bulk of the naphtha in the condensate has been re-formed. Actually the naphtha need not necessarily be re-formed. The high lead susceptibility of condensates permits the C.F.R. octane number to be increased with a minimum of tetraethyl lead. However, most refiners would prefer to re-form a substantial part of this material to produce a finished fuel with a high octane rating by the research method that more nearly approximates performance of the road. The straight-run gasoline from condensate in column 2, Table 1, may be examined in column 2 of Table 3.

If the motor-fuel value of the natural gasoline fraction in the condensate were used in these calculations instead of an assumed $0.025 per gallon, the gross difference in value between a barrel of crude and condensate would be $0.209 in favor of condensate. Furthermore, these calculations do not take into account the substantially higher processing costs involved in producing motor fuel from crude oil. Chemical costs for treating are eliminated, and corrosion, a considerable factor in the processing of most crude oils, can be ignored. The color-stable and low-sulphur condensate will do much to improve by dilution the poorer qualities of the refined uels in these respects.

TABLE 3.—*Disposal of Products*[a]

	1 Condensate	2 Motor Fuel	3 Bottoms	4 Gas
Cut per cent	100	83.2	13.2	3.6
Gravity	55.2	57.1	37.2	
Color	22	30		
Doctor	Sweet	Sweet		
Copper dish	Negative	Negative		
Vapor pressure, lb	10.1	4.9		
Int. oct. CFG-M, c.c		57.5		
Lead to 70 CFR-M, c.c		1.1		
	Degrees Fahrenheit			
1 boiling point	94	124	440	
5 per cent	140	150	464	
20 per cent	166	190	480	
30 per cent	192	204	489	
40 per cent	217	226	498	
50 per cent	237	240	507	
60 per cent	260	262	516	
70 per cent	294	278	534	
80 per cent	336	318	550	
90 per cent	400	352	590	
Maximum	490			
	568	402	652	
Recovery, per cent	97	98.0	98.0	
Loss, per cent	1.5	1.0	0.0	
Residue, per cent	1.5	1.0	2.0	

[a] Front end volatility of motor fuel, column 2 deficient. Natural gasoline available from total condensate will provide required volatility. Note, too, high lead susceptibility of motor fuel. Unstabilized condensate accounts for high loss shown in column 4.

From the dollar value of the component parts of the average condensate balanced against the products manufactured from crude oil, it would be anticipated that refiners, through their buyers, the pipe lines, would eagerly compete for condensate, particularly if it were available at the price of 40° A.P.I. crude oil. However, this material has not been sought by them; rather, it has generally been rejected. The reasons urged by refiners vary with their individual circumstances, but are encompassed by the following: (1) inadequacy of equipment for additional light end recovery, (2) insufficient re-forming facilities, (3) addition of straight-run gasoline would enforce idleness upon cracking equipment, (4) lower-gravity crudes make possible an over-all higher motor-fuel octane number and finally, (5) the need for burning oils that are present in larger quantities in crude oil.

Selective buying by pipe lines has caused condensate to be a drug on the market in several areas. It was not by deliberate choice, therefore, that the more recent plants have been designed to distill the condensate into its component parts. Other plants have added such facilities. Reasonably satisfactory fuels, including leaded grades, are produced entirely without re-forming. The plants built and building represent major investments. These plants are going to operate and as long as they operate they are going to produce. This production is finding, and will continue to find, a market. Table 2 shows a substantially higher net back to the recycling plant making motor fuel than to the refiner operating on crude oil, even without taking into account the transportation cost the refiner must pay on crude oil. This comparative net back will prevail whether there is a profit or loss on the operation. The refiner of crude oil cannot produce gasoline at as low a price as can the operator of a recycling plant.

With few exceptions, the production from these "field refineries" is greater than the local demand, wherefore a substantial part of the production moves in tank cars into the northern markets under exceedingly unhealthy marketing conditions, affecting orderly marketing quite out of proportion to the volume involved. In the writer's opinion, the plant operator would rather dispose of the whole product to one buyer, but that buyer would have to pay a price for the material commensurate with the price and value of high-gravity crude. The relative schedules obtaining in late 1938 and withdrawn at about the time condensate production began to appear were equitable and if in effect at this time would eliminate the marketing problem. Selective purchasing by pipe lines—and this is simply one aspect of selective purchasing—brings with it a chain of developments not always foreseen. Condensate is a raw material for production of motor fuel and, like crude oil, should find an outlet through the established channels of pipe lines and refineries.

Future Developments

As noted earlier in this paper, there will presently be a production of some 50,000 bbl. of condensate from some 30 plants (see Appendix), including the prospective major plants in sight. With few exceptions, these plants are in fields discovered more than two years ago. No gas-distillate field of any proportion has been discovered in the last year. While a number of smaller projects will be built to utilize gas from reservoirs already discovered, in point of volume of added production, they are not of great significance. Some of the old production will presently begin to decline as an offset. New production, therefore, is not likely to be maintained at anything like the pace of the immediate past when there was a big backlog of discovered fields. The industry may be said to be "caught up" and new projects will come along only with new discoveries. Of what magnitude these will be cannot be prophesied.

Although the volume of condensate is decidedly small compared with the amount of oil produced in Texas and Louisiana, it is not unnatural that some producers and refiners should seek to restrict the production from distillate wells as a means of curing a situation that has more fundamental causes for its ills. An effort in this direction was made in the Texas Legislature in the spring of 1939 but failed. There are controlling reasons of equity why it should fail again. But even in the severely prorated state of Texas, the production of ¼ to 1 bbl. of "crude" condensate is far below the allowable oil production per acre for most fields. Any restriction of recycling would be a penalty upon the highest type of conservation. The economics inherent in the business and the limitation of gas-distillate reservoirs will in and of themselves doubtless act as sufficient brakes and checks to overexpansion.

Summary

Condensate is essentially an additional source of crude oil. Where the reserves are available in sufficient quantities and a plant can be planned of the size justified by the extent of the reserves and available market, an extraction plant may be built with a reasonable expectation of profit. Excessive bidding for gas should be avoided if the venture money is not to be unduly risked. The greatest care should be taken to deflate estimates of recoverable reserves and the most scientific development plan should be selected and maintained.

If the pipe lines will not purchase the condensate at a price commensurate with its value as a source of end products, it will be converted by the plant operator and marketed as finished products if a profit can be made by this operation. This finishing process in the plant, especially where the raw material is not too volatile, can be justified on the basis of the prices of crude, motor fuel and kerosene prevailing at the present time.

The daily production of condensate in 1941 will represent little more than 3 per cent of the crude-oil production of Texas and Louisiana, and by coincidence about the same percentage of the crude oil produced in each state. Considered as crude oil, this volume of condensate should not present a problem of production or marketing. If it is converted into end products, a sizable question of disposal is posed for solution.

APPENDIX

Gas-sampling Methods

A sampling device designed by Black, Sivalls and Bryson for removing a representative sample of gas from condensate wells under flowing conditions consists of a $\frac{1}{16}$ in. internal-diameter sectional steel sampling tube with a steel-spring spider to hold the sampling tube in the center of the tubing. The sampling tube is forced down into the well tubing with a simple tube jack fitted with ball-bearing slips designed to operate at a maximum pressure of 4000 lb. The sample tube is forced down into the well tubing until its tip has passed below all takeoffs, chokes, shoulders or other obstructions. A sharp-edged, streamlined nipple attached to the end of the sample tube takes a continuous streamlined flow sample at a point below where turbulence occurs in the well head. The size of the nipple is chosen so that the ratio of its area to the area of the tubing is in the same proportion as the ratio of the flow to the charcoal meter is to the flow of the well. This provides equal velocities through the sampler and tubing, assuring a representative sample of gas.

The expansion valve is immersed in a hot glycerin bath so that the sampling rate can be held constant. In order to avoid losing condensate in the meter, the gas is passed directly from the expansion valve into the charcoal tube. The residue gas from the charcoal tube is measured in the meter and the volume is corrected for temperature and for shrinkage due to removal of the condensate.

Costs

Gas capacity, million cu. ft.	25	40	60[a]	60
Assumed value of condensate	$0.025	$0.025	$0.025	$0.025
Operating cost	0.0054	0.0037	0.0042	0.0031
Depreciation (5 years to 10 per cent salvage)	0.0067	0.0048	0.0053	0.0045
Cost of gas	0.0125	0.0125	0.0125	0.0125
Total cost per gallon	$0.0246	$0.0210	$0.0220	$0.0201

[a] This plant has facilities for cutting several end products; hence higher costs.

The price of 40° A.P.I. crude oil in the Long Lake field was $1.08 per barrel in the spring of 1940 and $1.28 in the Corpus Christi area. If a condensate manufacturer had a plant in both areas, processing 1 gal. gas in each plant, and if he paid 40 per cent for the gas, that gas would cost him $0.0126 for every gallon of condensate he produced at Long Lake, but it would cost him $0.0152 at Corpus Christi. In other words, the cost would be $0.0026 higher in the latter field.

This writer believes that ultimately operators of recycling plants will consider the experience of manufacturers of natural gasoline and profit by their example.

Recycling Projects in Operation

	Operating Company	Location
1.	Tide Water-Seaboard	Cayuga 1
2.	Tide Water-Seaboard	Cayuga 2
3.	Tide Water-Seaboard	Long Lake
4.	Byrd-Frost (Anco)	Long Lake
5.	Trinity Gas Corp.	Long Lake
6.	Agua Dulce Corp.	Corpus Christi
7.	Lockhart Petr. Co.	Corpus Christi
8.	Coastal Recycling Co.	Corpus Christi
9.	Corpus Christi Corp.	Corpus Christi
10.	Hosey Harrel	Bamel
11.	Portex	Logansport
12.	Process Oil Co.	Corpus Christi
13.	Abercrombie-Harrison	Old Ocean
14.	Sun Oil Co.	Sea Breeze
15.	Sun	Willow Slough
16.	McCoullum	LaBlanca
17.	American Liberty	Grapeland
18.	H. L. Hunt	Long Lake
19.	Trinity-Lone Star	Grapeland
20.	Gulf Plains	Stratton Etc.
21.	Roeser and Pendleton	Cayuga
22.	Coronado Corp.	La Rosa
23.	Davis	Alyce
24.	Gasoline Production Co.	Grapeland

Under Construction

25.	Shamrock	Opelika
26.	Ohio et al.	Cotton Valley
27.	Alexander-Sherrin	La Gloria
28.	Gulf States	McAllen
29.	Texas Company	Berwick, La.

Planned

1.	Humble et al.	Katy
2.	Atlantic	N. Tepetate
3.	Texas Co.	Francitas
4.	Standard Oil Co. Texas	Hidalgo
5.	Texas Co.	Bessemer
6.	Jackson and Geier	Grapeland

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DISCUSSION

(*L. F. Terry presiding*)

E. O. BENNETT,* Ponca City, Okla.—The author has made an excellent presentation of an important and fast-growing phase of the oil-producing industry, but I cannot agree with his statement that the effect of deviation is to a considerable extent nullified by reservoir temperature and that it is well to allow this factor as a cushion. The curves of Fig. 1 show the effect of temperature on deviation of a deep gas-distillate pool in Louisiana. At reservoir temperature, 200°F., the deviation is about 11 per cent. Since actual deviation is readily measured, it should be taken into consideration.

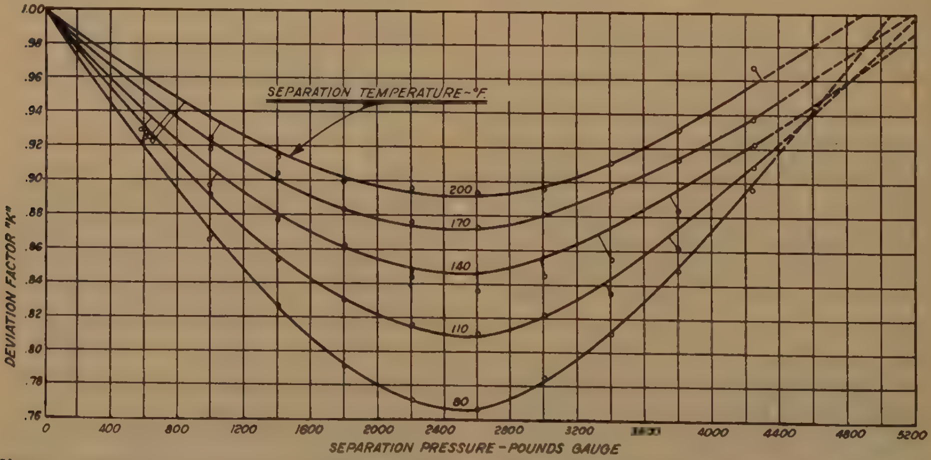

FIG. 1.—EFFECTS OF PRESSURE AND TEMPERATURE ON DEVIATION OF SEPARATED GAS FROM PERFECT GAS LAW (SUPERCOMPRESSIBILITY).

L. F. TERRY,* New York, N. Y.—What recovery factor of the condensate in place in the reservoir may be expected in reasonably good operating practice?

E. KAYE (author's reply).—I should say 60 to 75 per cent.

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* Chief Petroleum Engineer, Continental Oil Co.

* Chase National Bank.

Engineering Economics of Long Petroleum Pipe Lines

By Edgar G. Hill*

(New York Meeting, February 1942)

Much has been written and said recently about the methods used and materials and equipment employed in building the long tubes that criss-cross a great part of the United States, like the pattern of a spider's web. This paper will discuss the fundamentals of design of these lines from the economic as well as the engineering viewpoint, pointing out the effect of the volumes transported, and the load factor, on the unit costs of transportation, as well as the effects on costs of the character of the fluids the lines are called upon to handle.

Generally speaking, crude-oil pipe lines carry oil from the producing fields to the refineries. Sometimes part of the journey is by pipe line to a coastal point and tank ships are employed for the rest of the trip.

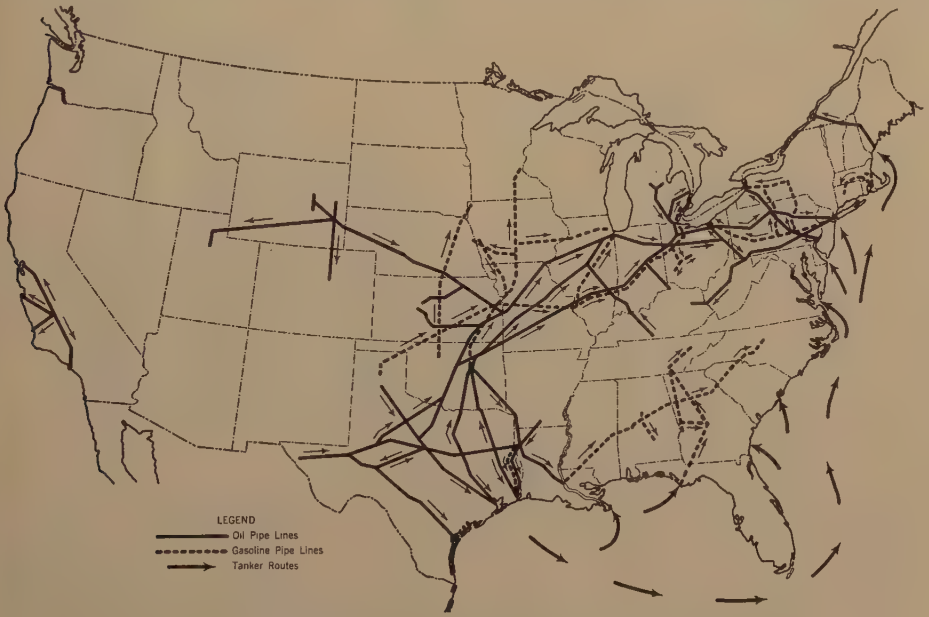

Fig. 1.—Directional flow of crude-oil and gasoline pipe lines.

The main lines of directional flow of crude oil through pipe lines in the United States are shown on Fig. 1, but this, of course, does not always show individual pipe lines.

Basic Formula for Flow of Crude Oil

The laws governing the flow of crude oil through pipes are well known. The basic

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flow formula can be simply expressed as follows:

$$P = \frac{KQ^2G}{D^5}$$

or

$$Q^2 = \frac{PD^5}{KG}$$

or

$$Q = \sqrt{\frac{PD^5}{KG}}$$

where Q = delivery per 24 hr., bbl. (42 gal.)

P = pressure loss per square inch per mile, lb.

D = inside diameter of pipe, in.

K = a factor depending on the volume and characteristics of the fluid handled and the diameter of the pipe.

G = the specific gravity of the fluid handled, water being taken as 1 at 60° F.

Therefore, the quantity of crude oil that a pipe line can handle varies:

1. Directly as the square root of the pressure drop per mile in the line.
2. Directly as the square root of the fifth power of the inside diameter of the pipe.
3. Inversely as the square root of the specific gravity of the oil.
4. Inversely as the square root of the factor K.
5. Inversely as the square root of the line length.

Factor K is determined from a knowledge of the velocity of the oil in the line; i.e., the capacity to be handled and the diameter of pipe to be used, the viscosity of the oil—that is, its internal resistance to movement—and the density of the oil. In ordinary practice, for oils of moderate viscosity, factor K usually ranges from 0.0024 to 0.0018 for a 6-in. line to 0.0013 to 0.0015 for a 24-in. line.

The usual pressure at the initial point is 800 to 1000 lb. per sq. in., 900 lb. being a fair average. Pumping stations are spaced along the lines at intervals of 25 to 75 miles. These stations restore the pressure that has been lost because of the friction of the fluid in the pipes or the effect of varying elevations.

The pressure drop per mile ranges from as much as 30 lb., on a line operating at high capacity with stations closely spaced, to as little as 10 lb. on lines where provision has been made for substantial later increase in capacity through addition of intermediate stations, or where the full economic capacity of the line is not being utilized. For the computation shown on the charts, Figs. 2 and 3, a pressure drop of 15 lb. per sq. in. per mile has been adopted, not because it is always the most economical but simply because it is satisfactory for comparative purposes.

APPLICATIONS OF BASIC FLOW FORMULA

The determination of the most economical pressure drop per mile in a long pipe line requires analysis in each individual case. It depends to some extent on the probable increase in capacity that may be needed later. If this is believed to be considerable, and not too long deferred, the line usually will be designed initially with a fairly low pressure drop and wide station spacing. The capacity can then be increased up to about 140 per cent of the initial capacity by doubling the number of pumping stations and increasing their installed horsepower proportionately to the increased capacity, without adding any more pipe.

On the other hand, should the price of pipe or the cost of construction be abnormally high at the time when or the place where the line is to be built, it might be found advisable to use a higher pressure drop per mile, which would require less pipe per unit of capacity but more pumping machinery. In such cases any additional capacity needed later would probably be provided by looping the line part way with a parallel pipe, and also adding to the station horsepower without increasing the number of stations. Thus the relationship between the cost of pipe in place and the cost of power is also an important consideration.

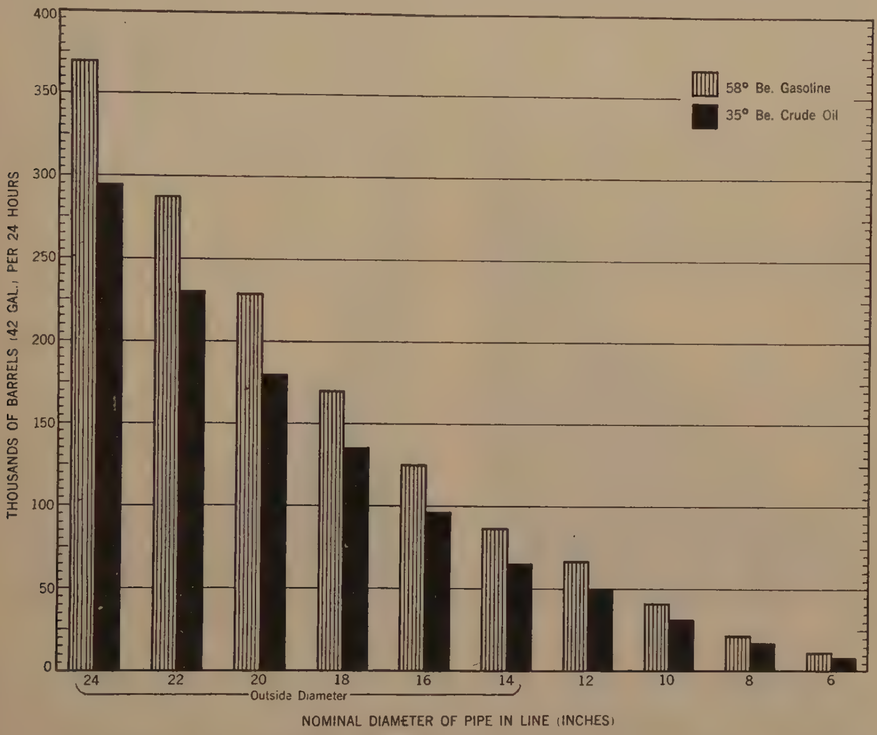

FIG. 2.—APPROXIMATE DAILY DELIVERY CAPACITY AT 100 PER CENT LOAD FACTOR OF LONG OIL AND GASOLINE PIPE LINES.

Operated with pressure drop of 15 lb. per sq. in. per mile and 900-lb. gauge station-discharge pressure (station fuel requirement included).

Assume that a long pipe line is to be built to handle 17,250 bbl. of 35°Bé. crude oil per 24 hr., and that this oil has a Saybolt viscosity at 60°F. of 150 sec., which is a good fluid crude. Experience indicates that an 8-in. line probably will be needed for these conditions, and the problem becomes that of determining the pressure drop per mile in an 8-in. line, which fixes the spacing of the pumping stations. If the trial analysis obviously gives too low a pressure drop per mile, computations will be made for a 6-in. line, the next smaller commercial pipe size.

From our tables and charts, the factor K for these conditions of volume, 8-in. pipe size and viscosity is determined as 0.00213 and the formula is set up as follows (35°Bé. crude having a specific gravity of 0.85):

$$P = \frac{0.00213 \times 17{,}250^2 \times 0.85}{8.071^5}$$

P = 15.7 lb. per mile; say 16 lb. for convenience.

In flat country then, if the discharge pressure at stations is to be 900 lb. and the intake at the next station down the line 100 lb., the stations will be spaced

$$\frac{900 - 100}{16} = 50 \text{ miles apart.}$$

Where lines are built in mountainous or rough country, an accurate profile of the pipe line is essential because the difference in elevation of the successive stations must be taken into account as well as the friction loss in determining the station spacing. However, it is assumed here that all stations are at the same elevation, or approximately so.

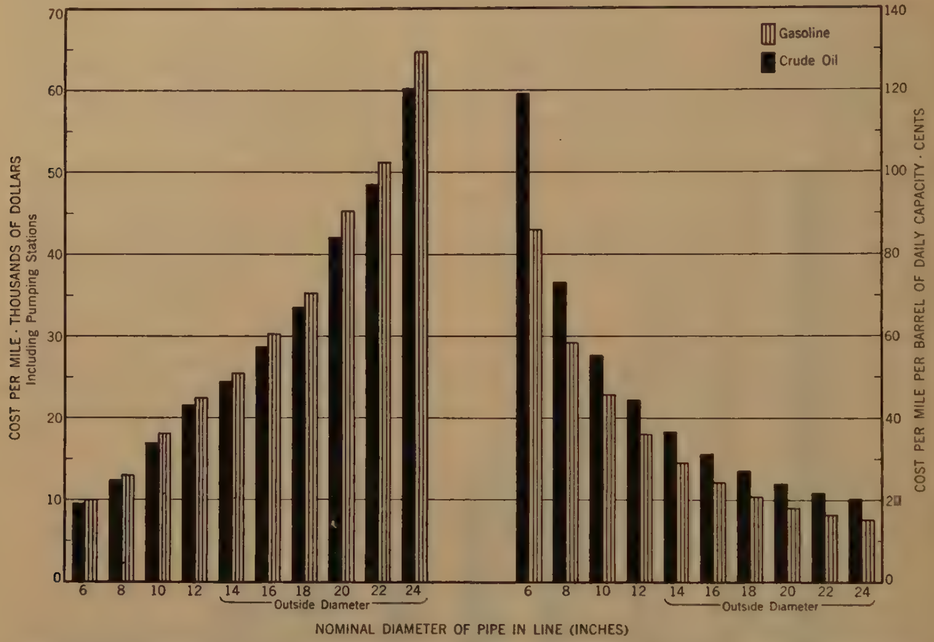

FIG. 3.—APPROXIMATE COST PER MILE OF LONG OIL AND GASOLINE PIPE LINES, INCLUDING PUMPING STATIONS.

Expressed per mile of line and per mile of line per barrel of daily capacity. Line capacity computed with 15 lb. per mile pressure drop.

HORSEPOWER REQUIRED FOR PUMPING

The power required in each station is computed as follows:

$$\text{HP} = \frac{\text{Gallons per Minute Pumped} \times \text{Net Pressure in Lb. per Sq. In.} \times 2.31}{3960 \times E}$$

E is the efficiency of the pumps employed.

Pumping station horsepower therefore is computed as follows:

$$\frac{17{,}250 \times 42}{1440} = 503 \text{ g.p.m.}$$

Pumps having an efficiency of 75 per cent will be used, therefore

$$\text{HP} = \frac{503 \times 800 \times 2.31}{2970} = 313$$

to which will be added 10 to 20 per cent as a safety factor and 350 to 375 hp. of drivers will be used in each pumping station, depending on the type used, whether electric or Diesel.

COMPARATIVE COSTS OF LINES

The line, then, is an 8-in. line operating at 900-lb. pressure with pumping stations spaced 50 miles apart, each containing 350 to 375 hp. of pumps plus any spare capacity desired.

With pipe costing $80 per ton, including freight, and the line installed in average pipe-line country from a construction standpoint, the cost of this line per 100 miles would approximate $1,262,000, including the two pumping stations and other appurtenant facilities necessary to a pipeline project. This is equivalent to $12,620 per mile, or 73¢ per mile per barrel of daily capacity.

We will now refigure the design of this line based on the use of 6-in. pipe operating at the same 900-lb. pressure, to determine comparative over-all cost.

The factor K for a 6-in. line handling 17,250 bbl. of the same crude per day is 0.00196 and the formula is set up:

$$P = \frac{0.00196 \times 17{,}250^2 \times 0.85}{6.065^5}$$

$$P = 60 \text{ lb.}$$

The station spacing is thus

$$\frac{900 - 100}{60} = 13.3 \text{ miles}$$

requiring 7½ pumping stations in 100 miles, or 15 in 200 miles.

The cost of the project for 200 miles of line, then, is:

200 miles of pipe line at $7500	$1,500,000
15 pumping stations, 350 hp. each	1,260,000
Other facilities	220,000
Total per 200 miles	$2,980,000
Average per mile	$ 14,900

A 6-in. line, therefore, is too small to handle economically 17,250 bbl. per day, not only from the standpoint of first cost but also from the standpoint of over-all operating costs, because of the large number of pumping stations required, all of which will require operating labor and will either use oil from the line for fuel or will operate on purchased energy of some kind. A 10-in. line would handle this volume easily with only one pumping station in 160 miles but the first cost of a 10-in. line with fewer stations would be so much higher than the cost of an 8-in. line with two pumping stations that an 8-in. line would be constructed.

There is, however, a range of capacities, say from 20,000 to 25,000 bbl. per day, where the choice between an 8-in. and a 10-in. line would have to be determined after a very careful calculation of present and future expected over-all costs including capital charges and operating expenses.

CAPACITIES OF LINES AND COST PER MILE

Fig. 2 shows the computed daily capacities, in barrels, of long pipe lines of various diameters, when handling 35°Bé. crude oil of moderate viscosity (150 S.U.S. at 60°F.) and when handling 58°Bé. gravity gasoline, the computed line capacities being based on station discharge pressures of 900 lb. and a pressure drop of 15 lb. per mile.

Fig. 3 shows the estimated approximate total investment cost per mile, including pumping stations, of crude-oil and gasoline lines from 6-in. to 24-in. diameter, inclusive; also, the cost per mile per barrel of daily capacity of such lines. The two charts of Fig. 3 are vital to an understanding of this paper because they show that while large pipe lines cost somewhat more per inch of diameter than small lines they cost much less when considered on a capacity basis.

EFFECT OF VISCOSITY ON OVER-ALL TRANSPORTATION COSTS

Most crude oils handled by long pipe lines are of moderate viscosity; that is, they are commonly known as light crudes, and usually have a high total gasoline content. A few crudes are so viscous that they must be heated before they can be pumped; and others that are fluid at summer temperatures become rapidly more viscous as the temperature lowers. When such oils are pumped in cold climates they must be heated or the delivery capacity of the line is sharply reduced.

In determining factor K in the basic pipe-line formula, the kinematic viscosity (i.e., the ratio of the absolute viscosity to the density of the crude oil to be pumped) is required. This is determined by the use of the Saybolt Universal viscosimeter. The

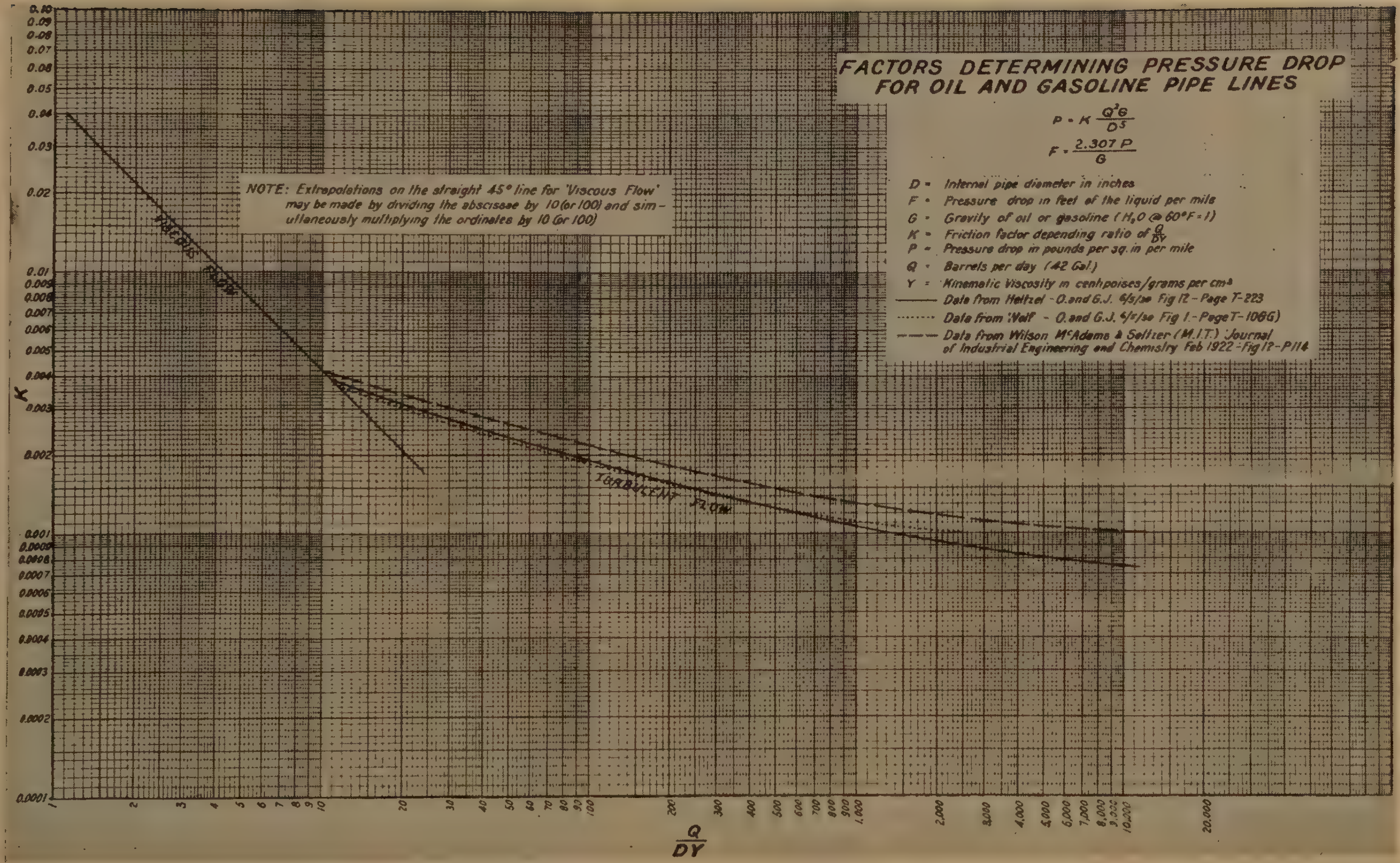

FIG. 4.—FACTORS DETERMINING PRESSURE DROP FOR OII AND GASOLINE PIPE LINES.

figure so determined is used in the expression

$$\frac{Q}{DY}$$

where Q = barrels transported for 24 hours,
D = internal diameter of pipe in inches,
Y = kinematic viscosity of oil in centipoises divided by density in grams per cubic centimeter.

After $\frac{Q}{DY}$ is determined the factor K may be determined by the use of a chart, Fig. 4, which shows the relationship between $\frac{Q}{DY}$ and K for any value of $\frac{Q}{DY}$.

To show the effect of viscosity on the pressure drop in pounds per square inch per mile of pipe line and, consequently, on the horsepower required to move the oil through the line, we will determine the station spacing and total horsepower required per 100 miles of line for two crudes of different viscosities but of the same specific gravity, using the 8-in. line handling 17,250 bbl. per day.

For crude A,

$$Q = 17{,}250$$
$$D = 8.071$$

Viscosity = 150 Saybolt Universal Seconds at 60°F.

From *Technologic Paper* 112 of the National Bureau of Standards (by W. H. Herschel), page 19, Eq. 13, a curve has been developed showing the relation between the S.U.S. viscosity and the kinematic velocity Y. From this curve, using S.U.S. at 150:

$$Y = 31.5$$
$$\frac{Q}{DY} = \frac{17{,}250}{8.071 \times 31.5} = 68$$

where

$$\frac{Q}{DY} = 68$$
$$K = 0.00213$$

and by substituting the value of K so determined in the basic formula

$$P = \frac{KQ^2G}{D^5}$$
$$P = 15.7 \text{ or, say, } 16 \text{ lb. per mile}$$

Thus, a 350-hp. station will be needed every 50 miles to handle this oil through an 8-in. line, two stations on a 100-mile line and four on a 200-mile line.

Crude B, however, is more viscous, with a Saybolt viscosity of 300 at 60°F. Y then becomes 65 and

$$\frac{Q}{DY} = \frac{17{,}250}{8.071 \times 65} = 32.9$$

From the curve of Fig. 4 a value for K is found of 0.0027 corresponding to 32.9 for $\frac{Q}{DY}$. The basic formula then becomes:

$$P = \frac{0.0027 \times 17{,}250^2 \times 0.85}{8.071^5} = 20$$

The station spacing then is

$$\frac{900 - 100}{20} = 40 \text{ miles}$$

and while the power required in each station is substantially unchanged, particularly if reciprocating pumps are used, five pumping stations will be needed in 200 miles of line with the 300 viscosity crude, against four with the 150 viscosity crude, an increase of at least 25 per cent in the pumping plant required to move the same amount of oil through line of the same size. Not only is the first cost increased by the additional stations but the operating cost is also greater, owing to the increased pumping-station labor, fuel, supplies and maintenance required.

If the line had already been built with a 50-mile station spacing, we would try to increase the station discharge pressure to 1100 lb., which would handle 17,250 bbl. of 300 viscosity crude. If that could not be done, the pressure could be held at 900 lb. and the pumps slowed down to deliver

$\sqrt{16/20}$ or 89.5 per cent of 17,250 bbl.,
or 15,440 bbl. daily.

In any event, the transportation cost per barrel is increased by the higher viscosity of the oil.

In almost all long lines, except those in the far South, the increased viscosity of most crude oil brought about by the lowered temperature in winter necessitates increased station pressures during winter months for normal deliveries, the alternative being reduced deliveries at the same station pressure. Some crudes, however, have almost a constant viscosity through operating temperature ranges. If these crudes are available for mixing with crudes having high viscosity at low temperature, better operating efficiency in winter will naturally follow.

Basic Costs of Transporting Crude Oil

Most crude-oil pipe lines are under the jurisdiction of the Interstate Commerce Commission, which publishes in some detail the operating statistics of all the lines under its control. These published data show that for the larger system the gross revenue, or barrelage handled times the tariff, averaged almost exactly 6¢ per barrel per 100 miles in the year 1937, the latest year for which complete figures are available. A barrel of crude oil weighs about 300 lb., so that 6¢ per barrel per 100 miles is equivalent to 4 mills per ton-mile, which may be taken as a measure of the basic cost of transporting crude oil by the larger carriers in 1937, including depreciation and return on investment. This is much less than comparable railroad freight rates.

There have been recent reductions in pipe-line tariffs, which amount in some cases to as much as 20 per cent, and it is probable that at the present time 5¢ per barrel per 100 miles, or 3⅓ mills per ton-mile, is a more accurate figure.

Effect on Costs of Increased Line Size

The large lines considered in arriving at this base cost are 10 and 12 in. in diameter. If by combining the crude requirements of a number of refiners, the capacity to be handled by a pipe line can be increased fivefold or sixfold over the rated capacity of any one of the present large lines—say to 200,000 or 250,000 bbl. daily—line diameters of 20 to 24 in. become possible.

This was the situation presented by the oil companies that sponsored the large crude-oil line from Texas to the Eastern Seaboard, construction of which was proposed last year in an effort to replace the tanker capacity that had been diverted from the usual routes to the service of Great Britain, but which was not approved by the S.P.A.B. on the ground that the large tonnage of steel required should be put to better use during the present emergency.

Without going into the merits of the positions taken by those who argued for and against this line, it is easy to show that the cost per barrel-mile for transporting oil from Texas to the Philadelphia or New York areas by such a system would be much lower than anything yet attained in pipe-line operation.

The principal items of cost entering into pipe-line tariffs are routine operating expenses, including pumping costs, maintenance, property taxes, depreciation and return on investment. Of these items, maintenance, property taxes, depreciation and return are all functions of capital investment. Many of the routine operating expenses are almost the same regardless of the diameter of the line—for example, it costs just about as much to dispatch and patrol a 12-in. line as a 24-in. line. Pumping costs, with the same station spacing, would not differ much for the labor required at the stations, whether medium size or large pumps were employed, and certainly would not increase more than in proportion to the diameter of the line. Administration costs would hardly increase in proportion to the diameter of the line.

Fuel at the station, however, would be consumed in proportion to the volume handled and would be about six times as much in total for a 24-in. as for a 12-in. line; but it would be about the same per barrel-mile, as on Fig. 3 it is shown that while the cost per mile of a 24-in. line is nearly three times that of a 12-in. line, its carrying capacity is nearly six times as much when operated under the same conditions of pressure and station spacing and handling crude of the same characteristics.

To be specific, the cost of a 12-in. line with a capacity of 50,000 bbl. of crude per day is estimated at $21,900 per mile at today's price levels, equivalent to 43.8¢ per mile per barrel of daily capacity.

A 24-in. line with a daily capacity of 295,000 bbl. of the same crude is estimated to cost $60,200 per mile, equivalent to only 20.4¢ per mile per barrel of daily capacity. The capital costs of transporting oil through the 24-in. line therefore are only 46.6 per cent as much per barrel of capacity as for a 12-in. line, and in comparison with capital costs of transporting oil through 8 and 10-in. lines, the economy in the use of lines of very large capacity is even more pronounced. This statement assumes, of course, that the same annual rates of return on investment, taxes, depreciation, amortization and maintenance are applicable in all cases.

The routine operating expenses in dollars, with the exception of pumping cost for the 24-in. line, might possibly be as much as 150 per cent of those of the 12-in., but on a per barrel daily capacity basis would then only be about one fourth as much, and the same should hold true of administration costs. Of the components of the total cost, then, only one item, fuel, would be the same on a per barrel basis, the other items being much less for the large line.

Fuel cost normally would be about one third of the total of all the routine operating costs on a big line, so that on a per barrel basis the total operating costs of the 24-in. line including fuel but excluding capital charges should be about 50 per cent of the costs on a 12-in. line. As the capital costs of the 24-in. line per barrel-mile have been computed to be about one half those of the 12-in. line, it is obvious that the over-all operating costs per barrel-mile for a 24-in. line would be about half those of a 12-in. line—or, say, 2½¢ per barrel per 100 miles—from which it can be readily deduced that as against the present tariff of 67¢ per barrel charged by the pipe-line carriers from the East Texas field to the New York area, a distance of about 1400 miles, the corresponding tariff on the proposed 24-in. line would probably not have exceeded 35¢ per barrel at a reasonably good load factor.

The proposed large line from East Texas to New York, if built, would thus accomplish the delivery of large volumes of Texas and Mid-Continent crude oil to the Eastern Seaboard refineries at transportation costs not far from those that existed before the present emergency, as most of this oil used by the Eastern Seaboard refineries traveled via pipe line from the fields to the Gulf Coast and thence by tanker to destination, the combined pipe-line and tanker transportation cost for this movement being around 35¢ per barrel in normal times.

FUNCTIONS OF PIPE LINES FOR REFINED PRODUCTS

The refined-products line, or gasoline pipe line, as it is usually termed, is really part of the marketing facilities of the owning company or companies. Long products lines date from about 1930, when Phillips Petroleum Co. built a 750-mile 8-in. carrier from its refinery at Borger, Texas, to the St. Louis area, and the former crude line of Tuscarora Pipe Line Co., which for many years had brought crude oil eastward into the New York area, was converted into a products line and its direction of flow reversed. Since that date, construction of products lines has proceeded at an accelerated rate and by the end of this year there will probably be about 13,000 miles of such lines in service.

Fundamentally, the purpose of a products line is either to enable a refiner whose plant is a long distance away from volume marketing areas to lay down his products in those areas on a cost basis that will allow him to compete on fairly even terms with refiners in or near such areas, or to enable him to compete on fairly even terms with other refiners also far from the market area, who may already have built products lines or who may have the advantage of water transportation. If it were not for such low-cost carriers of refined products as pipe lines and tank vessels, large refineries would have difficulty in existing except close to areas of great consumption, as they would be wholly dependent on the higher-cost railroad transportation for their products to remote market areas. As it now stands, a large refinery in the Panhandle of Texas, 1000 miles away, can profitably take advantage of low production costs at its location only because a products pipe line connects it with large consumer demand in cities as far removed as St. Louis and Chicago, and makes possible a terminal from which its products can move cheaply by water to other points on the Great Lakes.

Likewise, refiners on the Atlantic Seaboard can ship their products to markets in western Pennsylvania, Ohio and western New York, where they would have great difficulty in competing with refiners situated on the Ohio and Mississippi Rivers or on the Great Lakes were it not that their products lines to those markets afford cheap transportation of finished goods and their Eastern Seaboard refineries are supplied with crude largely by low-cost tank steamships.

Along the route of these products lines are terminals containing substantial storage capacity, from which deliveries can be made to the bulk plants in the surrounding areas by tank car or truck transport.

The broken lines on the map, Fig. 1, show the directional flow of much of the gasoline and finished products now handled by pipe lines. Most of the lines originate at refineries but some, such as the lines extending from eastern Long Island Sound into New England and the southeastern line from Port St. Joe, Fla., to Atlanta, Ga., and Chattanooga, Tenn., originate at terminals located on tidewater, to which the products are delivered by tank steamer from refineries that may be hundreds of miles away.

The Plantation Pipe Line, just completed in the Southeast, is one of the few common carriers of products. Most of the others are operated as plant facilities. It happens that the Plantation line serves markets that formerly were served by a combination of tanker, tank car and truck transport, and thus will supplant a certain amount of tanker capacity; and the same is doubtless true of the Southeastern Line. The Plantation Pipe Line originates at Baton Rouge at a terminal at the refinery of one of its owners, which also is equipped to receive the products of others into the same terminal direct from the tanker that has brought them from distant refineries.

All this construction of gasoline pipe lines definitely cuts the cost of moving finished products to market, and so permits competition in marketing areas that otherwise would not exist.

Handling Different Products through Pipe Lines

It has been found through experience that different refined products can be moved in slugs through a pipe line if sufficient velocity of flow in the line is maintained to keep the different fluids from mixing and contaminating each other. There will necessarily be some mixing at the zone of contact between the different products, but careful operation holds this to a low percentage. Badly contaminated products are either degraded and marketed as such, or shipped back to the refinery in tank cars for reprocessing. There is some ground for belief that more contamination relatively will be experienced in the operation of large-diameter lines than in the smaller ones, which operate satisfactorily when handling different products without the use of water or other separating medium. A dispatching system, comparing in exactness of operation with that used by the railroads, is necessary for efficient operation where different products are handled, because the arrival of the different products at the various points where they are to leave the pipe line must be figured in advance almost to the second and the terminal operators must be ready to handle them the moment they arrive.

Basic Principles Governing Flow of Gasoline in Pipe Lines

The basic principles that govern the handling of gasoline and other refined petroleum products through pipe lines are really the same as those governing the flow and handling of crude oil.

It happens that viscosities of the refined products are not determined in the same manner as for crude oil and it also happens that when the early gasoline lines were built not much was known precisely about the friction losses that would be realized, so that the lines were designed, generally speaking, as though they were to handle water and when the results of the lines' operations were determined the basic constant developed was the factor C in the Hazen-Williams formula covering the flow of water through long pipes. This formula used with varying constants has been the standard in determining the size of gasoline and products carriers and the constant C has been often taken at 130 for the average gasoline. Sometimes C has been determined for new lines to be initially higher than 130, but it has often been experienced that, owing to internal corrosion, rather startling decreases in the capacity of some of the lines have developed after only a few years of operation.

Daniel E. Sullivan, Chief Engineer of the Pure Oil Co., has outlined, in a very interesting paper presented before the Division of Production at the Annual Meeting of the American Petroleum Institute in San Francisco in November 1941, the experience of his company with internal corrosion on the 6-in. pipe line of the Detroit Southern Pipe Line Co., the gasoline line between Toledo and Detroit that was built in 1933. Mr. Sullivan states that initially on this line the constant C was 143.4 but that after 2½ years of operation the capacity of the line fell off to 74 per cent of its initial capacity and the constant C declined to 110.2. Fortunately, it has been possible to restore the capacity of this line to somewhat better than its original volume by the frequent use of an ingenious cleaning device, which removes the tuberculation from the interior wall of the pipe and also takes out much of the water, which is believed to be the basic cause of the corrosion trouble.

The Hazen-Williams formula for the flow of water is:

$$v = C \times r^{0.63} \times s^{0.54} \times 0.001^{-0.04}$$

where v = velocity per second, ft.,
c = a constant for a given pipe, the numerical value of which is affected by the roughness of the wetted inside of the pipe,
r = the mean hydraulic radius (diameter ÷ 4)
s = the slope of the pipe (pressure drop in feet of fluid ÷ length)

Using the foregoing formula as a basis and substituting the value of 130 for C, introducing the specific gravity of gasoline and expressing the rate of flow in barrels per hour, the Walworth Company, Inc., suggests the following modification* of the basic formula:

$$p^{0.54} = Q \times g^{0.54} \times F$$

in which p = pressure drop due to friction, lb. per sq. in. per mile,

Q = barrels of gasoline flowing per hour.

g = specific gravity of flowing gasoline referred to water as 1.0,

F = a factor that is a function of the inside diameter of the pipe (d, in inches) with which the formula constant is combined. Its value is $\frac{1.25}{d^{2.63}}$.

For convenience in the use of the formula, values of F for nominal sizes of A.P.I. line pipe are tabulated in Table 1.

TABLE 1.—*Numerical Value of Factor F*

NOMINAL PIPE SIZE A.P.I. LINE PIPE, IN.	NUMERICAL VALUE OF FACTOR F
1	1102.3×10^{-3}
1¼	535.79×10^{-3}
1½	357.24×10^{-3}
2	185.18×10^{-3}
2½	116.06×10^{-3}
3	65.548×10^{-3}
3½	44.723×10^{-3}
4	32.068×10^{-3}
5	17.698×10^{-3}
6	10.917×10^{-3}
8	5.3033×10^{-3}
10	2.9151×10^{-3}
12	1.8142×10^{-3}
14 o.d.	1.3979×10^{-3}
15 o.d.	1.1542×10^{-3}
16 o.d.	966.0×10^{-6}
17 o.d.	822.3×10^{-6}
18 o.d.	706.2×10^{-6}
20 o.d.	528.5×10^{-6}

This Walworth conversion of the basic Hazen-Williams formula presents a very convenient basis of computing the flow of gasoline through pipe lines, using a median figure of 130 for the friction constant.

In considering the economics of crude-oil and gasoline pipe lines, it cannot be too strongly emphasized that they must be kept internally clean to be operated efficiently. Deposits of paraffin or asphalt, which form on the interior of crude-oil pipe lines, are removed by the use of scrapers passed through the line with the crude from station to station. These scrapers operate through the cutting action of a multiplicity of curved steel blades in the cutterhead and are forced through the line by the action of the fluid on leather or fiber disks incorporated in the body of the scraper.

The tubercles that form on the inside of gasoline pipe lines are similar to those found on the inside of water pipes, and in their removal the conventional type of scraper is useless. A plug formed of alternate rings of circular wire brushes and rubber disks, as described by Mr. Sullivan in the paper cited, seems to be the best means yet devised of mechanically cleaning the inside of gasoline lines. Much work has been done and is being done toward the development and effective use of both liquid corrosion inhibitors introduced into the fluid stream and other chemical means of preventing this internal corrosion.

Figs. 2 and 3 show that a pipe line of a given diameter normally passes more gasoline than crude oil because of the lower viscosity and gravity of the refined products. The capacities shown for gasoline on these charts were computed by the use of the Walworth formula, using gasoline of 58°Bé. gravity. The increase in capacity possibly necessitates correspondingly greater horsepower in the pumping stations to realize it, so that the over-all cost of a gasoline line of a given diameter usually is somewhat greater than that of a crude-oil line designed for the same basic pressure drop per mile and, likewise, a very similar relation exists between the cost per mile of the various sizes of gasoline lines and crude-oil lines, and a similar reduction in the cost per barrel of capacity is shown for the large lines handling gasoline and for those handling crude oil.

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[*] See page 499, Catalog 89, Walworth Company, Inc.

It is basically necessary, therefore, to handle large volumes in order to obtain the lowest costs. It is undoubtedly this fact that has caused the cooperation between otherwise competitive interests in the construction of refined-products pipe lines such as the Great Lakes Pipe Line system, the Detroit Southern Pipe Line, the Plantation Pipe Line between Baton Rouge and Greensboro, N. C., and the Southeastern Pipe Line, which has recently been built between Port St. Joe, Fla., and Chattanooga, Tenn. It is a fair assumption that no one of the companies that have united in the construction of these lines had enough market for its own products in the territory served by the line to make a wholly owned line show enough savings over former transportation costs to be economically justifiable.

Importance of High Load Factor

The great influence of load factor on over-all costs of pipe-line transportation is primarily because it costs about the same to own and operate a pipe line of a given size and length regardless of the percentage of full capacity at which the line is being used. The capital costs, of course, are constant in dollars and the same applies to much of the administrative costs and to most items of pipe-line routine operation and maintenance. The pumping-station fuel will vary about in proportion to the quantities handled and the same is true to some extent of maintenance of pumping machinery, but probably 80 per cent of the total operating costs of a pipe-line system, including capital charges, are entirely independent of the volume handled.

It will be readily seen, therefore, that in order to realize the full potentialities of pipe lines in reducing the transportation costs of petroleum and its products, not only are large-diameter lines effective but such lines must be operated at high load factor; that is, the average daily throughput divided by the throughput for which the line was designed must show a quotient representing a load factor as near unity as possible. Storage tanks along the route are commonly used to increase load factor and the use of products lines to handle furnace oil in the winter, when gasoline consumption is usually lighter, is, of course, a valuable help in the same direction.

This means that in designing pipe lines great care should be taken to make sure that they are built not so large in comparison with the annual volume of crude or products expected to be handled through them that it will be difficult to operate them under an annual load factor of 75 per cent or better.

A large line that would operate at 100 per cent load factor with a cost of say 3¢ per barrel per 100 miles would probably show a cost of about 3.25¢ at 90 per cent load factor, 3.63¢ at 75 per cent and 5.4¢ at 50 per cent, so that good load factor is fully as important as large volume in reducing costs of pipe-line transportation.

DISCUSSION

(*L. F. Terry presiding*)

P. Diserens,* Harrison, N. J.—Analogous presentations of the problem of gas pipe lines have been available for some time, but insofar as I know Mr. Hill is the first to discuss broadly the oil pipe line with special emphasis on the related engineering economic and practical factors involved.

Mr. Henry C. Lehn, Consulting Engineer of Worthington Pump and Machinery Corporation, has shown that the design of gas pipe lines, including a determination of the dimensions of the line, the pump-station spacing and other controlling factors, is subject to accurate mathematical analysis. Formulas suggested by him have been used extensively and are well known to the gas engineer.

Mr. Hill's comparison of costs of the 6-in. and 8-in. lines suggests the possibility of a mathematical solution such as Mr. Lehn's to obtain the diameter for which the cost for a specified delivery capacity will be minimum. The result would require modification to suit commercial pipe sizes, but, as in all solutions for minimum, the cost would be increased much less than the amount of deviation from the theoretical diameter for minimum cost. The formula would show, of course, the relative values of the various factors involved.

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* Consulting Engineer, Worthington Pump and Machinery Corporation.

In setting up the Lehn formula to show the minimum cost of an oil pipe line for a specified capacity, the steps are as follows:

In the basic flow formula as given in Mr. Hill's paper,

$$P = \frac{KQ^2G}{D^5}$$

K is of the form

$$C\left(\frac{Y}{DV}\right)^n$$

the value of n depending upon the roughness of the pipe. Using the value of K as 0.00213 and the corresponding other conditions, and putting

$$Y = 0.22T - \frac{180}{T}$$

and

$$n = 0.234$$

for smooth pipe, there is obtained:

$$P = 0.004\left(\frac{T^2 - 820}{T}\right)^{0.234}\frac{Q^{1.77}G}{D^{4.77}} \qquad [1]$$

and if the total installed horsepower is H costing B dollars per horsepower, the total cost of the station is:

$$C_1 = \frac{B\left(\frac{T^2 - 820}{T}\right)^{0.234} \times Q^{2.77}GL}{14{,}700{,}000ErD^{4.77}} \qquad [2]$$

r being the ratio of required to installed horsepower and E the pump efficiency.

The cost of the line may be written:

$$C_2 = AtDL + cL$$

where t is the pipe thickness, A a constant involving cost of pipe and c a constant independent of the pipe dimensions. The total cost of line and stations is then:

$$C = AtDL + cL + \frac{B\left(\frac{T^2 - 820}{T}\right)^{0.234} \times Q^{2.77}GL}{14{,}700{,}000Er\,D^{4.77}} \qquad [3]$$

Then for the minimum

$$\frac{dc}{dD} = 0$$

$$AtL - \frac{B\left(\frac{T^2 - 820}{T}\right)^{0.234} \times Q^{2.77}GL}{3{,}070{,}000Er\,D^{5.77}} = 0$$

or

$$D = 0.075\,\frac{(T^2 - 820)^{0.04}}{T}\;\frac{(BG)^{0.173}}{AtEr}\,Q^{0.48} \qquad [4]$$

In this equation Q is the predominating factor, variations in the relative costs of line and stations are much less and variation in the viscosity is of no appreciable effect, except in its slight modification of the exponent of Q.

The graph of diameter, pressure and horsepower in Fig. 5 has been plotted, using the costs of stations and line as given in the article for the 6-in. or 8-in. line. The cost of \$240 given for the stations seems rather high. If \$150, then the line diameters would be reduced about 8 per cent. Also, pipe quotations over a considerable range of diameters indicate that $At^{0.8}\,D^{1.06}\,L$ represents the cost of the pipe more accurately than the straight-line equation, but as the total cost of the line is taken at a percentage increase over the pipe cost, in amount depending upon the nature of the terrain, this modification is not important. A constant should be added to the station cost also, but this, like the line cost constant, will disappear in the differentiation.

For the oil pipe line various relationships appear that differ from corresponding ones in calculations for gas pipe lines, and that have the effect of eliminating several factors present in the latter. In particular, since the horsepower is directly proportional to the pressure drop, and the latter directly proportional to the length, the total horsepower is independent of the number of stations, which is not true for the gas pipe line. Further, the horsepower is dependent only upon the difference between the initial and terminal pressures, and not upon their absolute values, which is not true for the gas pipe line. For these reasons, the stress and the pressure drop between stations are eliminated as factors of the minimum. Otherwise expressed, the pressure range can be from 2000 to 1000 or 1100 to 100 without affecting the solution. The expression for the minimum is thus more readily obtained.

There are, of course, other items in Mr. Hill's paper that deserve special comment. One in particular is worth mention. On page 237 Mr. Hill indicates that the power required for each station remains substantially unchanged when the viscosity of the oil to be handled changes from 150 S.U.S. at 60°F. to 300 S.U.S. at 60°F., "particularly if reciprocating pumps are used." It should be remembered, however, that for the centrifugal pump running at constant speed and capacity the power required is affected substantially by the viscosity of the oil. An increase in viscosity from 30 S.U.S. to 200 S.U.S. would involve an increase in power of approximately 6 per cent and an increase from 30 S.U.S. to 1000 S.U.S. would involve an increase in power of some 40 per cent. These facts must be taken into careful consideration in selecting the type of equipment best suited for handling any particular kind of oil.

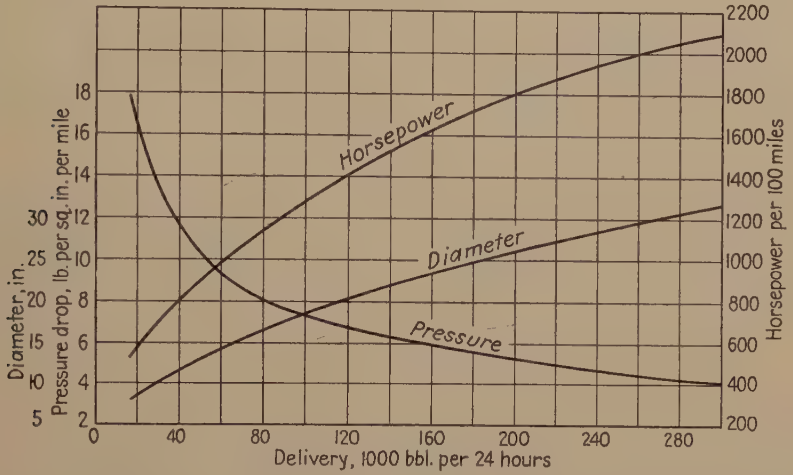

FIG. 5.—PRESSURES AND DIAMETERS FOR MINIMUM TOTAL FIRST COST OF OIL PIPE LINES.

World Consumption of Petroleum and Its Substitutes in 1941

By V. R. Garfias[*] and R. V. Whetsel,[*] Members, and J. W. Ristori,[*] Associate Member A.I.M.E.

(New York Meeting, February 1942)

World consumption of petroleum and its substitutes in 1941, the amount of which obviously is largely conjectural, is estimated at 2,066,653,000 bbl. This is 48,689,000 bbl. more than the previous year and is an all-time high. Except for the United States, this figure does not include consumption for military purposes. Consumption in the United States also reached an all-time high during 1941, totaling 1,492,000,000 bbl., or 158,230,000 bbl. more than the previous peak year of 1940. On the other hand, it is estimated that civil consumption in countries outside of the United States decreased 109,541,000 bbl. as compared with the previous year.

Demand for military purposes and/or additions to stocks in countries outside of the United States is estimated at 304,507,000 bbl. during 1941, compared with 209,635,000 bbl. in 1940. This increase was due largely to blitzkrieg warfare on several fronts, especially Russia; entailing large expenditures of petroleum by both sides because of the immense area covered by the fighting forces, the long supply lines necessary and the intensity of the fighting.

It is interesting to note in this connection that Axis-controlled countries, excluding Japan, had an estimated production of approximately 89,000,000 bbl. of petroleum and its substitutes in 1941. The peacetime consumption of these countries in 1938, for example, was about 183,000,000 bbl. It is believed that the minimum to which civil consumption could possibly be reduced in wartime is 20 per cent of that of peacetime, which would call for a minimum consumption of 37,000,000 bbl. in these countries in 1941 for civil purposes. This

Table 1.—*World Petroleum Balance Sheet*

Thousands of Barrels

Year	Production of Petroleum and Its Substitutes	Civil Consumption of Petroleum and Its Substitutes[a]	Excess Production over Consumption			United States		Foreign Military Consumption and Additions to Stocks
			United States	Foreign	World Total	Excess Exports over Imports	To Stocks	
1932	1,362,039	1,348,407	R13,011	26,643	13,632	28,781	R41,792	55,424
1933	1,467,128	1,406,923	67,427	R7,222	60,205	60,254	7,173	53,032
1934	1,562,834	1,507,599	26,164	29,071	55,235	64,013	R37,849	93,084
1935	1,702,793	1,614,475	53,027	35,291	88,318	75,474	R22,447	110,765
1936	1,864,997	1,795,560	52,209	17,228	69,437	74,890	R22,681	92,118
1937	2,121,337	1,914,856	161,445	45,036	206,481	115,677	45,768	160,713
1938	2,062,090	1,917,758	124,047	20,285	144,332	139,420	R 9,077	153,409
1939	2,182,883	2,022,763	86,222	73,898	160,120	134,811	R30,082	190,202
1940	2,266,345	2,017,964	85,461	162,920	248,381	46,715	38,746	209,635
1941	2,360,160	2,066,653	R16,000	309,507	293,507	9,000	R11,000	304,507

[a] Includes U. S. military consumption.

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[*] Cities Service Co., New York, N. Y.

would leave a balance of only 52,000,000 bbl., or 142,000 bbl. daily, available for military purposes in 1941, so that any additional supplies must have come from storage.

Taking 20 per cent of the 1938 civil demand in Japan for petroleum and its substitutes, a consumption that already had then been substantially reduced by the war with China, would give only 5,000,000 bbl. The 1941 production of petroleum and substitutes is estimated at 8,200,000 bbl., leaving 3,200,000 bbl., or 8800 bbl. daily, for military purposes, indicating almost with certainty that Japan must either capture new sources of supply or continue to make withdrawals from storage.

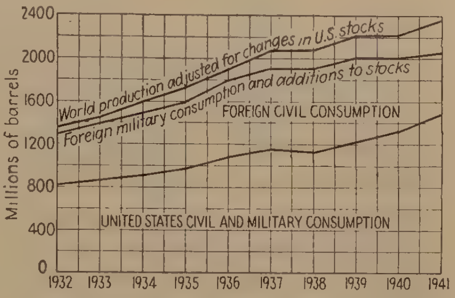

FIG. 1.—WORLD PRODUCTION AND CONSUMPTION OF PETROLEUM AND ITS SUBSTITUTES.

TABLE 2.—*World Production of Petroleum and Its Substitutes*
THOUSANDS OF BARRELS

Country	1940			1941 (Estimated)		
	Crude Oil	Petroleum Substitutes	Total	Crude Oil	Petroleum Substitutes	Total
United States	1,353,214	66,017	1,419,231	1,400,000	76,000	1,476,000
Russia	215,409	1,300	216,709	226,000	1,500	227,500
Venezuela	184,761	1,000	185,761	222,000	1,200	223,200
Iran	78,592	1,000	79,592	78,000	1,000	79,000
Netherlands Indies	60,830	2,000	62,830	61,500	2,000	63,500
Mexico	40,350	1,000	41,350	41,120	800	41,920
Rumania	43,231	2,500	45,731	36,000	2,100	38,100
Germany	4,544	23,000	27,544	4,500	32,000	36,500
Colombia	26,067	900	26,967	24,000	850	24,850
Argentina	20,486	500	20,986	22,000	500	22,500
Trinidad	20,219	300	20,519	21,000	300	21,300
Peru	13,427	1,000	14,427	12,800	900	13,700
Canada	5,500	3,455	8,955	6,300	3,800	10,100
Iraq	25,725		25,725	10,000		10,000
Japan	3,439	4,500	7,939	3,200	5,000	8,200
Egypt	6,053	200	6,253	7,600	300	7,900
Burma	7,979	150	8,129	7,700	150	7,850
Bahrein Island	7,047	160	7,207	7,000	170	7,170
United Kingdom		7,000	7,000		7,000	7,000
Sarawak and Brunei	7,074		7,074	6,800		6,800
Saudi Arabia	5,365		5,365	5,800		5,800
France	496	3,500	3,996	480	3,900	4,380
Poland	3,891	150	4,041	3,300	130	3,430
Hungary	1,755	100	1,855	2,500	150	2,650
British India	2,250		2,250	2,300		2,300
Ecuador	2,349	37	2,386	1,500	25	1,525
Albania	1,659		1,659	1,400		1,400
Estonia		1,400	1,400		1,350	1,350
Austria	719		719	700		700
Miscellaneous	445	2,300	2,745	735	2,800	3,535
Total	2,142,876	123,469	2,266,345	2,216,235	143,925	2,360,160

TABLE 3.—*World Consumption of Petroleum and Its Substitutes*
THOUSANDS OF BARRELS

Country	1940						1941					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	596,640[a]	68,776	501,014	24,690	142,650	1,333,770	671,000[b]	70,000	560,000	32,000	159,000	1,492,000
Russia	29,500	46,000	72,000	10,000	22,500	180,000	23,000	38,000	54,000	7,500	16,000	138,500
Canada	26,413	833	20,298	1,379	4,500	53,423	22,000	800	22,000	1,400	4,500	50,700
Argentina	8,530	1,300	20,000	500	2,520	32,850	8,500	1,300	20,100	600	2,500	33,000
United Kingdom	22,000	3,800	20,000	2,000	2,200	50,000	13,000	2,000	14,500	1,200	1,300	32,000
Japan	8,000	1,500	12,800	1,800	2,100	26,200	7,200	1,400	14,000	1,700	2,000	26,300
Mexico	4,209	1,062	13,844	269	3,905	23,289	4,300	1,100	14,000	280	4,000	23,680
Germany	14,000	500	14,200	2,300	4,000	35,000	7,000	400	9,500	1,500	2,600	21,000
Netherlands West Indies	230	50	13,000	50	3,400	16,730	250	50	15,800	60	4,000	20,160
British India (ex. Burma)	3,000	6,000	5,000	950	850	15,800	3,000	6,000	5,000	950	850	15,800
Italy	2,500	500	9,500	750	800	14,050	2,100	560	10,000	720	800	14,180
Australia	9,500	1,100	3,000	450	900	14,950	7,000	1,000	3,200	400	800	12,400
Rumania	1,200	1,450	8,947	180	1,300	13,077	1,000	1,300	8,200	170	1,100	11,770
Netherlands East Indies	1,500	2,000	6,250	250	1,500	11,500	1,500	2,000	6,500	260	1,500	11,760
Venezuela	1,345	206	8,000	90	400	10,041	1,400	210	9,000	100	400	11,110
France	9,800	700	8,000	1,000	2,000	21,500	3,000	300	5,300	400	1,000	10,000
Union of South Africa	5,850	650	3,150	350	500	10,500	5,000	500	3,100	320	400	9,320
Iran	550	1,050	5,400	360	2,300	9,660	520	1,000	5,200	340	2,100	9,160
Brazil	3,200	800	4,700	300	500	9,500	2,800	750	4,500	290	450	8,790
Egypt	830	2,300	3,000	170	400	6,700	850	2,500	3,100	180	430	7,060
Cuba	820	100	4,100	60	140	5,220	870	110	4,900	70	160	6,110
British Malay	1,100	400	3,400	130	230	5,260	1,150	450	3,700	140	230	5,670
Chile	900	60	4,100	95	80	5,235	910	65	4,300	100	90	5,465
Trinidad	135	70	4,330	35	430	5,000	140	75	4,600	40	450	5,305
Uruguay	900	300	3,500	80	130	4,910	950	310	3,600	80	120	5,060
Philippine Islands	1,200	380	2,550	120	150	4,400	1,250	400	2,700	130	160	4,640
Hawaiian Islands	1,260	200	2,595	145	100	4,300	1,300	200	2,700	150	110	4,460
New Zealand	2,900	220	1,200	135	280	4,735	2,600	210	1,200	130	260	4,400
China	790	1,600	1,400	190	230	4,210	770	1,500	1,400	190	230	4,090
Panama Canal Zone	150	30	2,950	30	40	3,200	160	30	3,100	30	40	3,360
Netherlands	1,600	1,000	2,000	300	400	5,300	900	500	1,480	120	200	3,200
Colombia	1,112	130	2,100	40	160	3,542	1,100	120	1,800	40	140	3,200
Peru	833	186	1,948	30	200	3,197	810	180	1,900	30	180	3,100
Aden	20	13	4,875	2	90	5,000	14	10	3,000	1	50	3,075
Spain	2,300	120	1,320	140	120	4,000	1,600	100	1,100	120	100	3,020
Sweden	2,200	300	1,650	150	200	4,500	1,000	200	1,590	80	130	3,000
Ceylon	340	210	2,300	25	75	2,950	300	200	2,300	20	70	2,890
Puerto Rico	570	90	1,150	40	50	1,900	600	90	1,300	50	60	2,100
Irish Free State	1,000	500	300	70	230	2,100	900	500	290	60	220	1,970
Jamaica	200	60	1,390	10	40	1,700	230	70	1,600	15	50	1,965
Denmark	1,100	400	1,140	110	150	2,900	500	300	830	70	100	1,800
Belgium	1,700	90	1,030	230	250	3,300	700	250	510	140	200	1,800
Palestine	360	440	670	30	200	1,700	320	400	700	30	180	1,630
Norway	800	150	1,120	40	90	2,200	500	140	860	30	70	1,600
Hungary	610	500	490	100	100	1,800	530	400	400	80	80	1,490
Hong Kong	100	80	1,050	40	30	1,300	100	80	1,100	40	30	1,350
Portugal	620	380	450	80	50	1,580	500	300	400	60	40	1,300
Iraq	250	190	2,115	45	600	3,200	100	80	800	20	250	1,250
Burma	160	40	800	40	200	1,240	150	40	800	40	200	1,230
French West Africa	220	80	2,860	30	10	3,200	90	40	1,000	14	5	1,149
Guatemala	135	20	900	10	35	1,100	130	20	870	10	40	1,070
Greece	550	150	1,650	70	100	2,520	160	80	680	30	50	1,000
Switzerland	600	70	1,140	15	75	1,900	180	40	635	5	40	900
Turkey	380	300	380	50	15	1,125	300	220	304	36	10	870
Finland	540	200	50	50	60	900	410	160	40	40	50	700
Kenya and Uganda (inc. Zanzibar)	350	80	250	30	20	730	270	60	210	20	10	570
Algeria	550	180	260	50	60	1,100	250	90	110	20	30	500
French Morocco	510	60	210	30	90	900	210	35	100	15	40	400
Yugoslavia	310	200	320	60	110	1,000	110	100	130	20	40	400
Poland			Included with Germany						Included with Germany			
Czechoslovakia			Included with Germany						Included with Germany			
Miscellaneous	5,078	2,462	4,429	551	1,050	13,570	4,024	1,839	3,859	404	748	10,874
	784,050	152,618	822,575	51,326	205,895	2,017,964	811,508	141,164	849,898	53,090	210,993	2,066,653

[a] Includes 7,150,000 bbl. of butane propane. [b] Includes 9,000,000 bbl. of butane propane.

TABLE 4.—*Consumption of Petroleum and Its Substitutes in "Miscellaneous" Countries*

BARRELS

Country	1940						1941					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubri-cants	Miscel-laneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubri-cants	Miscel-laneous	Total
Sarawak	14,000	34,000	733,500	4,500	14,000	800,000	13,000	32,000	740,000	4,000	15,000	804,000
Siam	180,000	210,000	300,000	32,000	40,000	762,000	190,000	210,000	320,000	34,000	40,000	794,000
Honduras	380,000	90,000	260,000	30,000	40,000	800,000	370,000	85,000	260,000	30,000	40,000	785,000
Indo China	250,000	255,000	145,000	30,000	100,000	780,000	230,000	240,000	140,000	25,000	90,000	725,000
Gold Coast	220,000	80,000	170,000	45,000	35,000	550,000	200,000	70,000	140,000	35,000	25,000	470,000
Southern Rhodesia	238,000	21,000	93,000	23,000	55,000	430,000	220,000	17,000	80,000	19,000	40,000	376,000
Dominican Republic	108,000	35,000	195,000	9,000	5,000	352,000	110,000	35,000	200,000	9,000	5,000	359,000
Ecuador	180,000	46,000	60,000	15,000	135,000	436,000	160,000	35,000	45,000	13,000	95,000	348,000
Bolivia	130,000	23,000	230,000	28,000	28,000	439,000	120,000	21,000	150,000	11,000	28,000	330,000
Panama	190,000	50,000	45,000	9,000	10,000	304,000	195,000	50,000	55,000	9,000	10,000	319,000
Belgian Congo	171,000	21,000	33,000	25,000	20,000	270,000	150,000	17,000	30,000	22,000	17,000	236,000
Iceland	115,000	30,000	59,000	5,600	400	210,000	120,000	38,000	70,000	7,000	500	235,500
Costa Rica	140,000	8,000	45,000	4,000	15,000	212,000	150,000	8,000	52,000	4,000	15,000	229,000
Nicaragua	110,000	20,000	65,000	7,000	11,000	213,000	115,000	18,000	68,000	7,000	11,000	219,000
Italian East Africa	200,000	4,000	35,000	18,000	193,000	450,000	100,000	2,000	16,000	9,000	90,000	217,000
Tunis	220,000	110,000	130,000	20,000	5,000	485,000	100,000	40,000	60,000	10,000	5,000	215,000
Estonia	110,000	55,000	66,000	23,000	26,000	280,000	70,000	50,000	54,000	19,000	20,000	213,000
Nigeria	140,000	56,000	29,000	16,000	4,000	245,000	120,000	50,000	23,000	12,000	3,000	208,000
Malta	50,000	90,000	99,000	8,000	3,000	250,000	38,000	70,000	90,000	7,000	2,000	207,000
Sierra Leone	12,000	13,500	217,000	1,500	1,000	245,000	9,000	10,000	180,000	1,200	700	200,900
Bulgaria	120,000	160,000	140,000	30,000	40,000	490,000	40,000	50,000	65,000	10,000	10,000	175,000
El Salvador	59,000	20,000	82,000	4,000	5,000	170,000	60,000	20,000	80,000	4,000	4,000	168,000
Latvia	130,000	190,000	15,000	12,000	28,000	375,000	50,000	90,000	10,000	5,000	13,000	168,000
Syria	140,000	130,000	72,000	15,000	23,000	380,000	60,000	50,000	40,000	5,000	7,000	162,000
Newfoundland	118,000	23,000	11,000	11,000	2,500	165,500	109,000	21,000	10,000	10,000	2,000	152,000
Libya	85,000	30,000	153,000	12,000	30,000	310,000	35,000	15,000	70,000	6,000	15,000	141,000
Portuguese East Africa	62,000	25,000	34,000	13,000	16,000	150,000	54,000	22,000	30,000	12,000	15,000	133,000
British Guiana	29,000	12,500	83,000	5,200	300	130,000	28,000	13,000	85,000	5,200	300	131,500
Madagascar	78,000	31,000	29,000	1,000	1,000	140,000	72,000	28,000	26,000	1,000	1,000	128,000
Bermuda	17,000	18,500	93,400	600	500	130,000	14,000	17,000	94,000	500	500	126,000
Lithuania	150,000	31,000	51,300	17,000	700	250,000	60,000	14,000	39,000	7,000	300	120,300
Barbados	50,000	14,000	50,000	3,000	2,000	119,000	45,000	13,000	48,000	3,000	2,000	111,000
Martinique	72,000	10,000	22,000	3,000	3,000	110,000	70,000	10,000	25,000	3,000	3,000	111,000
Tanganyika	45,000	30,000	45,000	1,000	200	121,200	40,000	25,000	41,000	900	100	107,000
Fiji Islands	40,000	9,000	47,300	3,500	200	100,000	40,000	10,000	50,000	3,500	300	103,800
Cyprus	25,000	13,000	58,800	3,000	200	100,000	22,000	12,000	60,000	3,000	200	97,200
Haiti	50,000	23,000	23,000	3,000	2,000	101,000	45,000	21,000	23,000	2,900	1,900	93,800
Others	650,000	440,000	410,000	60,000	155,000	1,715,000	400,000	310,000	290,000	35,000	120,000	1,155,000
Total	5,078,000	2,461,500	4,429,300	550,900	1,050,000	13,569,700	4,024,000	1,839,000	3,859,000	404,200	747,800	10,874,000

Chapter IV. Production

Introduction

By James Terry Duce,* Member A.I.M.E.

The symposium on production for the year 1941 contains few papers on the foreign situation. Rigid censorship prevails in various countries, as the question of the volume of petroleum supplies has become one of great strategic importance. This is even truer than in the last war, owing to greater mechanization of armies.

It has always been the policy of officers in charge of the symposium to refrain from publishing information that might possibly injure national or private interests. At the close of the war we hope again to publish full and accurate records of production abroad.

Excerpts from Circular to Authors

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from the Circular to Authors.

The field is the unit in this tabulation. In cases of fields extending across State boundaries, such as Rodessa, it is suggested that each State author treat the section of the field in his State as a unit, and by a footnote indicate that the field extends into an adjacent State.

Each space in Table 1 may represent one of four possibilities; either it is not applicable to the particular field, or the proper entry is not determinable, or the proper entry may be determinable but is not determinable from data available to the author, or the proper entry is determinable. When spaces are not applicable, leave blank; in spaces where the proper entries are determinable but not determinable from data available to the author, please insert *y*; in spaces where the proper entries are determinable by the author, make such entries. *y* implies a hope that in some future year a definite figure will be available.

The entry of a zero is a positive declaration, and an important declaration where it is in order.

Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely *y*. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entry need not be hedged to such extent as when the quantities are definite yet can be ascertained only approximately by the author.

In cases under definite headings but where figures are only approximate, the author may use *x*.

It is thought that the nearest whole numbers are sufficiently accurate for our purposes except as to percentage of sulphur in oil. If an author desires to report any other figures to tenths, he may do so.

The quantity of gas produced should include, where possible, gas sold or otherwise marketed, and gas blown into the air, burned as flares or otherwise wasted. Segregation of these figures would be interesting if the authors can make such segregation. In any event, the figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

Under the columns on "Depth," the average depth to the top of the productive zones and to the bottom of the productive wells, when subtracted, should give the approximate thickness of the productive zone. For fields where this is not true because of unusually high dip or for some other reasons, it is suggested that the authors indicate in their text the approximate average thickness of the productive zone.

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The net thickness of the producing formation should be the thickness of the producing zone, less the estimated amount to cover the portions of the zone that do not yield oil, such as dense shales, etc. It is recognized that for some fields the authors can only make rough guesses; in such cases, they should enter either *x* or *y*, whichever is appropriate, and production per acre-foot will have to be treated in a similar manner. Average production per acre-foot can be calculated by those interested from the figures given.

In classifying wells as to producing methods, enter all wells that are not "flowing" in the column headed "Artificial Lift." If desirable, add footnotes to indicate whether the lift is "pumping," "gas lift" or "air lift."

It is recognized that for many fields it would be very difficult to determine accurately the quantity of each gravity of oil produced. However, the approximate weighted average gravity, which will be representative of the total production can be determined sufficiently accurately to constitute significant information.

FOOTNOTES TO COLUMN HEADINGS—TABLE I

[a] All fields to be listed alphabetically for the district; or alphabetically by counties in alphabetical order.

[b] Areas where both oil and gas are produced, unless gas is marketed outside the field, are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

[c] Wells producing both oil and gas are classified as "Producing Oil." Gas wells are those producing gas, but include those producing wet gas, from which casinghead gasoline may be produced.

[d] State by letters, as indicated, type of operation: PM, pressure maintenance from early life of field; RP, field repressuring in its later life; SR, repressuring operations of secondary recovery type.

[e] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[f] S, sandstone; H, shale; L, limestone; OL, oölitic limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; Gw, granite wash; P, serpentine; Cgl, conglomerate.

[g] Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[h] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

Oil and Gas Development in South Arkansas in 1941

By Alec M. Crowell* and J. W. Sanders,† Members A.I.M.E.

While the production of crude oil and condensate in South Arkansas increased only 1.7 per cent over the 1940 figure, complete utilization of gas produced with the oil and condensate, and heretofore wasted, was beginning to be evidenced. There were 26,229,264 bbl. of oil and condensate produced in South Arkansas during 1941, as against 25,790,380 bbl. for the year 1940. (Fig. 1.)

Since 1936, deep producing sands have been discovered in 18 fields and during that period only 40 per cent of the total state production has come from Upper Cretaceous formations while 60 per cent came from the Lower Cretaceous and Jurassic formations. The gas produced with crude oil and condensate from the latter formation contains large quantities of hydrogen sulphide, the maximum being 6900 grains per 100 cu. ft. in the Patton pool of Lafayette County.

Gas Utilization

During the latter part of 1940 and the early part of 1941, pilot plants were placed in operation to determine whether the hydrogen sulphide and deleterious material in South Arkansas gases could be removed economically. The Federal Government desired to build a large aluminum plant in the Ouachita Valley and was seeking cheap fuel for the generation of electricity. The fact that the gases were produced with appreciable quantities of crude oil and condensate made it available at a very low price, since the state's conservation law prohibits the flaring of any gas. As a result of these experiments the first large-scale unit for the processing of gases containing hydrogen sulphide was placed in operation on Sept. 1, 1941.

The plant is in the Magnolia oil field, Columbia County. It processes residue gas from the Shell Oil Company's gasoline plant in that field and also raw gas from the Village field, 6 miles east of the Magnolia field. The gas entering the desulphurization unit is laden with approximately 1400 grains of hydrogen sulphide per 100 cu. ft. and is stripped to a content of 4 grains per 100 cu. ft. The capacity of the plant is 15 million cu. ft. of gas treated daily under a pressure of 160 lb. per sq. in. The cost of treatment, exclusive of depreciation, is appreciably less than 1¢ per 1000 cubic feet.

Two other plants of much greater capacity have been announced and priorities have been granted, which should bring the total amount of gas treated to 150 million cu. ft. daily. The gas to be treated will have a maximum hydrogen sulphide content of 4500 grains per 100 cu. ft. and will be processed under a pressure of 600 lb. per sq. in. These developments are something entirely new in field practice for the industry.

The fact that this heretofore wasted gas is available at very low cost has led to the location of some eight war industries within the state, in addition to the aluminum plant.

Recovery of Sulphur

The Susearch Corporation and the Southern Acid and Sulphur Co. placed in operation during 1941 pilot plants to de-

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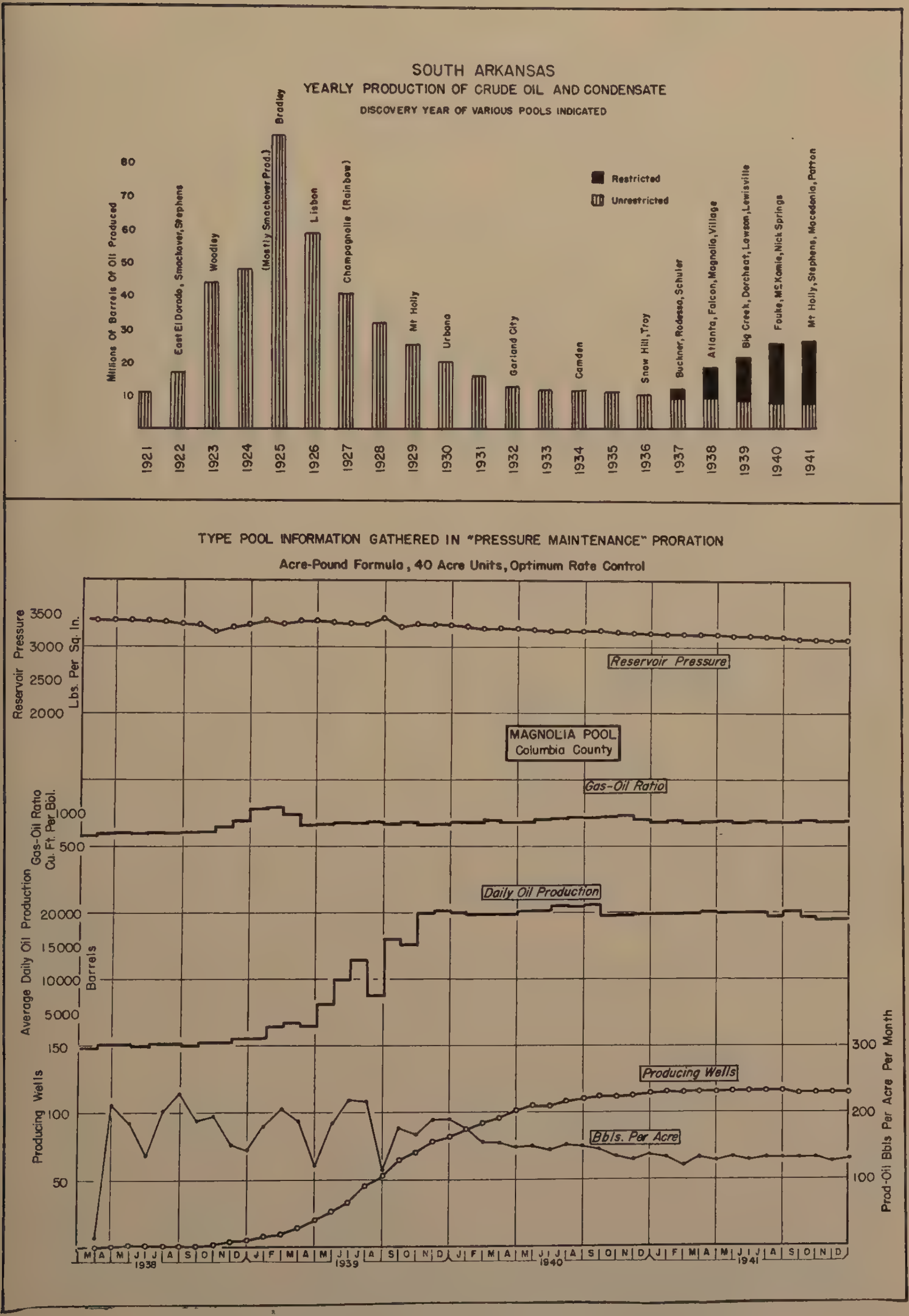

FIG. 1.—PRODUCTION AND PRORATION DATA, SOUTH ARKANSAS.

Table 1.—*Oil and Gas Production in South Arkansas*

Line Number	Field, County	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
										During 1941		End of 1941			Number of Wells	
			Oil	Gas[b3]	To End of 1941	During 1941	To End of 1941	During 1941[6]	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
1	Atlanta, *Columbia*	1938	800	0	1,848,431	1,016,236	2,513	1,626	21	5	1	0	20	0	18	2
2	Big Creek, *Columbia*	1939	0[2]	400[2]	68,030	42,455	1 572	1,061	1	0	0	0	0	1	1	0
3	Bradley, *Lafayette*	1925	80	0	186,705	0	0	0	6	0	0	0	0	0	0	0
4	Buckner, *Columbia, Lafayette*	1937	1,040	0	2,657,401	815,161	680	220	26	4	0	0	26	0	13	13
5	Camden, *Ouachita*	1934	10	0	37,850	0	0	0	1	0	1	0	0	0	0	0
6	Champagnolle, *Union*	1927	2,040	*x*	14,956,356	334,576	*x*	*x*	240	3	9	10	73	1	0	73
7	Dorcheat, *Columbia*	1939	720	0	1,124,828	669,338	11,369	7,080	18	10	0	0	18	0	18	0
8	East El Dorado, *Union*[1]	1922	1,420	*x*	9,517,591	105,416	*x*	*x*	195	4	8	0	50	3	0	50
9	El Dorado (South), *Union*	1920	8,000	*x*	48,358,567	422,052	*x*	0	1,116	1	7	13	196	0	0	196
10	Fouke, *Miller*	1940	280	0	201,970	156,405	2*x*	*x*	7	5	0	0	6	0	0	6
11	Garland City, *Miller*	1932	300	0	2,042,475	81,745	*x*	*x*	28	0	19	0	9	0	0	9
12	Irma, *Nevada*	1921	900	0	7,062,889	203,554	*x*	0	150	0	0	4	73	0	0	73
13	Lewisville (Stamps), *Lafayette*	1939	400	0	466,227	99,407	284*x*	59*x*	19	1	0	0	19	0	0	19
14	Lisbon, *Union*	1925	2,700	*x*	6,774,999	67,819	*x*	0	356	0	0	0	143	0	0	143
15	Macedonia, *Columbia*	1941	0[2]	1,000	129,562	129,562	1,749	1,749	7	7	0	0	0	7	7	0
16	Magnolia, *Columbia*	1938	4,600	1,200	18,225,782	7,122,807	15,950	6,332	116	1	1	0	115	0	113	2
17	McKamie, *Lafayette*	1940	0[2]	2,400	971,707	895,562	6,726	6,179	15	12	0	0	0	15	15	0
18	Mt. Holly (McDonald), *Ouachita*	1929	60	0	117,085	0[4]	0	0	6	0	0	0	0	0	0	0
19	Mt. Holly, *Union*	1941	80[2]	0	10,423	10,423	42	42	1	1	0	0	1	0	1	0
20	Nick Springs, *Union*	1940	130	0	487,132	306,662[5]	0	0	14	1	1	0	13	0	1	12
21	Patton, *Lafayette*	1941	40	0	12,792	12,792	102	102	1	1	0	0	1	0	1	0
22	Rodessa, *Miller*	1937	2,150	200	6,308,434	499,044	34,184	1,852	123	0	5	0	66	7	0	66
23	Shuler, *Union*	1937	5,450	400	26,504,289	6,026,314	31,445	7,120	180	3	1	99	75	0	60	15
24	Morgan sands	1937	350	0	2,291,426	223,896	1,844*x*	174*x*	18	3	0	0	13	0	2	11
25	Jones sand	1937	4,000	200	21,001,197	4,925,362	26,522	6,174	146	0	0	99	47	0	43	4
26	Reynolds oölite	1937	1,100	200	3,211,666	877,056	3,079	772	16	0	1	0	15	0	15	0
27	East Shuler, *Union*	1941	160	0	36,322	36,322	246	246	4	4	0	0	4	0	4	0
28	Smackover, *Ouachita Union*	1922	25,760	*x*	389,304,369	5,352,519	*x*	*x*	3,759	16	20	45	1,619		0	1,619
29	Heavy	1922	16,000	*x*	333,927,889	4,685,239	*x*	*x*	*y*	1	*y*	39	1,149	0	0	1,149
30	Light	1922	9,600	*x*	55,161,677	639,797	*x*	*x*	*y*	15	20	6	467	0	0	467
31	Snow Hill	1936	160	*x*	214,803	27,483	*x*	0	6	0	0	0	3	0	0	3
32	Stephens, *Columbia, Nevada, Ouachita*	1922	3,000	*x*	6,801,930	247,905	*x*	*x*	317	11	10	0	199	0	0	199
33	Troy, *Nevada*	1936	500	0	1,968,110	379,555	*x*	*x*	48	13	0	0	41	0	0	41
34	Urbana, *Union*	1930	500	0	6,253,411	834,801	*x*	*x*	84	15	0	0	49	1	35	14
35	Village, *Columbia*	1938	600	0	1,153,282	360,832	5,694	1,732	12	1	1	0	11	0	11	0
36	Total		147,643	6,000+	553,588,949	26,229,264	112,558+	35,400+	6,871	119	84	171	2,827	35	298	2,552

[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Including several small producing areas.

[2] Areas of Big Creek, McKamie, Macedonia, Mt. Holly, are not yet fully defined.

[3] Big Creek and McKamie are classified as gas fields; however, the latter produces a considerable quantity of high-gravity oil or distillate. Although Dorcheat is officially termed an oil field the fluid produced and the gas-oil ratios are comparable with those of McKamie. Village has relatively high gas-oil ratios. Magnolia and the Jones sand and Reynolds oölite of Schuler have gas caps which are not being produced.

[4] Fields abandoned in 1931. [5] Producing from five sands in the upper part of the Hosston formation.

[6] Gas volume produced is estimated from average gas-oil ratios.

TABLE 1.—(*Continued*)

	Reservoir Pressure, Lb. per Sq. In.			Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
										Depth, Avg. Ft.					
Line Number	Initial	Avg. at End of 1941	Repressuring Operation[d]	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole. Ft.
1	3,844	3,580		45.3	0.47	Reynolds	Jur	OL	15	8,202	8,227	25	A	Smackover	8,332
2	3,723	3,723		68.6	0.05	Reynolds	Jur	OL	13.4	7,959	7,995	36	A	Smackover	7,999
3	*y*	*x*		26.3	0.43	Buckrange	CreU	S	Por	2,785	2,790	5	A	Paluxy	3,555
4	3,200	2,640		31.5	2.0	Reynolds	Jur	OL	15	7,200	7,260	30	A	Smackover	7,444
5	*y*	*y*		16.2	2.56	Nacatoch	CreU	S	Por	1,356	1,369	13	ML	Hosston	2,500
6	*y*	*y*		22.3 34.0	1.42 2.00	Tokio Travis Peak	CreU CreL	S	Por	2,780 3,340	2,800 3,350	15	NL	Eagle Mills salt	6,911
7	4,243	3,531		57.4	0.55	Reynolds	Jur	OL	15	8,815	8,875	60	A	Smackover	9,028
8	*y*	*y*		20.5 32.7	1.92 1.07	Nacatoch	CreU	S	Por	2,170	2,180	10	TL	Cotton Valley	6,003
9	*y*	*y*		33.2	1.15	Nacatoch	CreU	S	Por	2,100 2,550 2,950	2,177	20	ANL	Smackover	7,820
10	1,485	*y*		30.3	1.30	Paluxy	CreU	S	Por	3,583 3,655	3,607 3,660	24 5	F	Smackover	9.550
11	*y*	*y*		31.7 47.4	1.26 0.44	Paluxy Rodessa	CreL	S	Por	2,925 4,200	2,935 4,215	10	ML	Smackover	7,310
12	*y*	*y*		14.1	2.70	Nacatoch	CreU	S	Por	1,150	1,179	27	AF	Travis Peak	3,735
13	1,450*x*	*x*		42.7	0.66	Blossom Rodessa	CreU CreL	OL-S	17	3,400	3,500	20	TF	Smackover	7,420
14	*y*	*y*		34.0	1.08	Nacatoch	CreU	S	Por	2,100	2,120	20	ML	Smackover	6,821
15	4,130	3,981		62.1	0.13	Reynolds	Jur	OL	14	8,870	8,955	75	A	Smackover	9,020
16	3,465	3,129		39.2	0.90	Reynolds	Jur	OL	16.1	7,350	7,600	100	A	Smackover	7,824
17	4,365	4,233		58.3	0.30	Reynolds	Jur	OL	Por	9,125	9,300	106	A	Eagle Mills salt	9,980
18	*y*	*x*		30.0	*y*	Hosston	CreL	S	Por	2,800	2,813	7	ML	Hosston	3,378
19	3,180	3,160		40.0	0.77	Reynolds	Jur	OL	20.5	7,146	7,172	26	A	Smackover	7,373
20	1,600	*y*		39.6 39.4	0.80	Hosston	CreL	S	Por 5.0	3,153 3,736	3,161 3,762	30	AF	Smackover	6,819
21	4,380	4,110		47.5	0.60	Reynolds	Jur	OL	Por	9,312	9,503	30	A	Smackover	9,503
22	2,500*x*	*y*		42.9	0.38	Rodessa	CreL	LS-OL	30	6,050	6,100	25	AF	Rodessa	6,514
23															
24	2,000*x*	*x*		41.9	0.56	Cotton Valley	Jur	S	16	5,600	6,975	30	AL	Smackover	8,328
25	3,520	1,491	RP	34.6	1.46	Cotton Valley	Jur	S	20.2	7,530	7,610	42	A	Smackover	8,328
26	3,465	3,129		36.8	0.91	Reynolds	Jur	OL	16.7	7,600	7,635	26	A	Smackover	8,328
27	2,509	2,200		45.2	0.36	Cotton Valley	Jur	S	25	5,580	5,810	14	AL	Smackover	7,702
28															
29	*y*	*y*		19.8 23.1	2.02 2.36	Nacatoch Graves Tokio	CreU	S	Por	2,000 2,450 2,600	2,025 2,475 2,610	40	Af	Eagle Mills salt	7,255
30	*y*	*y*	SR	20.8 27.3	1.77 2.24	Nacatoch Meekin	CreU	S	Por	2,000 2,275	2,025 2,300	30	ALf	Igneous	7,973
31	*x*	*x*		36.2	1.08	Reynolds	Jur	OL	25.0	4,800	4,960	30	AF	Eagle Mills salt	5,708
32	*y*	*y*		12.6 30.6	2.87 1.60	Nacatoch Buckrange	CreU	S	Por	1,500 2,100	1,510 2,110	15 7	NLF	Smackover	6,053
33	*x*	*x*		14.1 22.0	2.24 2.51	Nacatoch Tokio	CreU	S	Por	1,243 2,160	1,250 2,167	10	F	Eagle Mills salt	6,143
34	*x*	*x*		18.9 32.7	2.03 1.14	Nacatoch Hosston	CreU CreL	S	Por	2,270 3,550	2,280 3,560	10	A	Cotton Valley	4,501
35	3,350	3,255		51.8 41.9	0.75 0.80	Smackover	Jur	OL	14	7,390	7,450	50	A	Smackover	7,603
36															

termine the feasibility of transforming to commercial sulphur the hydrogen sulphide removed at the plants. These experiments have been successful and two large sulphur-recovery plants will be built. Utilization of production from gas-distillate wells, therefore, is complete in South Arkansas. The fact that an active water drive exists in all limestone fields precludes the necessity of repressuring to prevent underground condensation of gas.

TABLE 2.—*Lease Blocks Held in* 1941[a,b]

Block	Acres	County	Centering Around	Lessee	Formation	Expiration Date
Pigeon Hill........	10,000	Bradley	16-17S-12W	C. H. Murphy, Jr.	Smackover lime	1947
State Line.........	1,720	Columbia	3-4-20S-21W	Magnolia	Prospect	1947
Spring Hill........	3,000	Columbia	12-20S-23W	Magnolia	Prospect	1947
Magnolia Townsite.	1,200	Columbia	23-17S-21W	Phillips et al.	Prospect	Mar. 1942
College Hill........	2,500	Columbia	13-15S-20W	Carter	Prospect	Mar. 1948
Emerson..........	4,000	Columbia	26-18S-21W	Carter	Prospect	1946
E. McNeil.........	1,800	Columbia	10-16S-20W	Carter	Prospect	Jan. 1949
Smithland.........	2,500	Columbia	28-17S-22W	Carter	Prospect	Dec. 1941–1942
Taylor............	2,500	Columbia	12-19S-23W	Carter	Prospect	Dec. 1947
S. E. Village.......	1,760	Columbia	32-17S-18W	Carter	Prospect	July 1948
10-17-22...........	1,500	Columbia	10-17S-22W	Carter	Prospect	1951
Stamps............	1,720	Lafayette	26-16S-23W	Grimes Bros.	Prospect	1945
Patton............	5,000	Lafayette	20-17S-24W	Tide Water Assn.	Prospect	
Kress City.........	2,640	Lafayette	15-17S-24W	Sinclair-Prairie	Prospect	1950
N. McKamie......	2,000	Lafayette	11-17S-23W	Carter	Prospect	1949
Texarkana.........	2,500	Lafayette	3-16S-28W	Carter	Prospect	April 1949
W. Lewisville......	4,000	Lafayette	30-16S-24W	Carter-Texas	Prospect	1949–1950
Lisbon Townsite....	1,200	Union	36-16S-17W	Lion Oil	Prospect	1949–1950
New London.......	2,000	Union	3-18S-12W	Phillips et al.	Prospect	1949
Hi Bank...........	8,800	Union	25-18S-15W	Root-Murphy	Prospect	1947
Caledonia.........	3,000	Union	11-19S-15W	Carter	Prospect	June 1948
Wilmington........	1,000	Union	15-17S-13W	Stanolind	Prospect	Feb. 1949

[a] Not tested.
[b] Explored by seismograph.

NEW FIELDS

Three new deep limestone pools, Macedonia of Columbia County, Mt. Holly of Union County and Patton of Lafayette County, were discovered during the year 1941. Other discoveries were in the Cotton Valley formation, being East Schuler of Union County, "Smart area" of Stephens in Columbia County, and the Catesville pool, which produced intermittently after its discovery but was abandoned by the end of the year with only one well drilled. None of the pools mentioned is fully developed.

The Barnsdall Oil Co., in its Edgar Bond No. 1 well, sec. 11, T. 15 S., R. 24 W. Lafayette County, discovered a Smackover limestone pool as the year ended. Production from the pool was not put into the tanks until Jan. 1, 1942. However, some testing was done the last week in 1941. The formation uncovered consists of three stratigraphic members. The top, or oölitic limestone, was encountered at 6304 ft. and extended to a depth of 6373 ft. This member was highly saturated and had a relatively high permeability and porosity. The second member was a dense, banded lime and was found to have a relatively low permeability and porosity. The third or lower member extended from 6419 ft. to the indicated water level at 6520 ft. This member was soft and cavernous but somewhat less permeable than the oölitic or first member.

East Schuler.—The Atlantic Refining Company's Burns No. 1, sec. 13, T. 18 S., R. 17 W., Union County, was completed in the Cotton Valley formation on June 2, 1941. The total depth drilled was 7702 ft. to the Smackover lime and a test showed it to be nonproductive. It was then plugged back and perforated at 5542 to 5546 ft. in the Cotton Valley formation and flowed 93 bbl. per day of 47° gravity oil on $\frac{15}{64}$-in. tubing choke with initial bottom-hole pressure of 2509 lb. per sq. in. Four wells were completed by the end of the year, with 36,322 bbl. produced. The discovery resulted from seismograph work.

Macedonia.—The McAlester Fuel Company's Lizzie Franks No. 1, sec. 16, T. 18 S., R. 21 W., Columbia County, was completed in the Smackover (Reynolds oölite) limestone on July 8, 1941. The total depth drilled was 9020 ft. The well was perforated from 8906 to 8914 ft. and flowed 340 bbl. a day on an $\frac{18}{64}$-in tubing choke. The fluid was 60° gravity and the gas-condensate ratio was 13,500 cu. ft. per barrel. The initial bottom-hole pressure was 4130 lb. per sq. in. Seven wells were completed to the end of the year, with 129,562 bbl. of condensate produced. The discovery resulted from seismic exploration.

Mt. Holly.—The Atlantic Refining Company's Mary E. Davis No. 1, sec. 15, T. 17 S., R. 18 W., Union County, was completed in the Smackover (Reynolds limestone) on Nov. 11, 1941. The total depth drilled was 7373 ft.; production comes from 7157 to 7177 ft. On test, the well flowed 230 bbl. on an $\frac{11}{64}$-in. tubing choke of 38° gravity oil with a gas-oil ratio of 2120 cu. ft. per bbl. Only one well had been completed at the end of the year and 10,423 bbl. produced. The initial bottom-hole pressure was 3180 lb. per sq. in. The discovery resulted from seismograph work.

Patton.—The Tide Water Associated-Seaboard's Moore No. 1 well, sec. 29, T. 17 S., R. 24 W., Lafayette County, was completed in the Reynolds formation on Sept. 14, 1941. Total depth drilled was 9503 ft. and production is from 9312 to 9340 ft. On test the well flowed 342 bbl. of 45.5° gravity oil with a gas-oil ratio of 3330 cu. ft. per barrel. The initial bottom-hole pressure was 4380 lb. per sq. in. and production to end of year was 12,792 bbl. The gas contained 6900 grains H_2S per

TABLE 3.—*Blocks Tested in 1941*[a]

Block	County	Lessee	Tested	Result	Operator—Farm	Location	Total Depth, Ft.	Formation	Expiration Date	Remarks
Macedonia	Columbia	Atl. McAlester	7- 8-41	Cond.	McAlester—Franks No. 1	16-18S-21W	9,020	Smackover lime	Mar. 1945	
S. Warnock Springs	Columbia	Carter Oil	6- 9-41	Dry	Phillips—Warnock No. 1	1-17S-20W	7,525	Smackover lime	1948	
Patton	Lafayette	Tide Water	9-14-41	Oil	Tide Water—Moore No. 1	29-17S-24W	9,503	Smackover lime	Mar. 1949	
Midway	Lafayette	Barnsdall	1- 2-42	Oil	Barnsdall—Bond No. 1	11-15S-24W	6,530	Smackover lime	Drill Cont.	Sweet Oil
E. Schuler	Union	Atlantic	5-21-41	Dry-Oil	Crescent—Burns No. 1	13-18S-17W	7,703	Dry	1946–47	Prod. Ctn. V.
Mt. Holly	Union	Atl. Carter	11- 4-41	Oil	Atlantic—Davis No. 1	15-17S-18W	7,373	Dry	1942–47	7166–68
Catesville	Union	C. H. Murphy, Jr.	4- 1-41	Oil	Murphy-Cates C No. 1	33-18S-15W	7,818	Dry	1949	Prod. Ctn. V.
Kiblah	Miller	Carter	3-30-41	Dry	Louark—Hendricks No. 1	27-19S-27W	6,505	Glen Rose lime	1949	
Ogamaw	Ouachita	Ark. Fuel	7-18-41	Dry	Ark. Fuel—McGaughey No. 1	6-15S-18W	5,336	Smackover lime		

[a] Explored by seismograph.

100 cu. ft. Only one well was completed by the end of the year and early in 1942 the well was plugged back to the Cotton Valley formation and all operations ceased. The discovery resulted from seismograph work.

Development and Exploration

Twenty-three seismograph crews were working in the state as the year 1941 ended. An average of five crews worked continuously throughout the year. (Tables 2 and 3.)

There were 210 wells drilled, 44 of which were dry wildcats. Of the 165 field wells drilled, 119 were oil producers (including 6 discovery wells), 1 well was a gas well, and 45 were dry and abandoned.

One repressuring project began operations during 1941, in the Schuler field, Union County. The majority of the operators in that field unitized their holdings, closed 100 of the 146 wells to production, obtained production from wells of low gas-oil ratio and used some of the closed wells for injecting gas back to the gas cap.

Regulation of Production

The Arkansas Oil and Gas Commission continued to control and prorate the production from all oil pools discovered after 1937. To the standard proration formula based on acreage and bottom-hole pressure were added two volumetric formulas, these being placed in effect in the Dorcheat and Village pools. Spacing was increased to one well for each 160 acres in "condensate" or "gas-cap" pools. Forty-acre spacing is standard for oil fields in Arkansas.

The Office of the Petroleum Coordinator for National Defense, in a letter made public on Oct. 28, 1941, by Mr. Ralph K. Davies, had the following to say concerning regulation of production in South Arkansas:

> This office is aware of the excellence of the present Oil and Gas Conservation Law of the State of Arkansas and of the sound judgment, efficiency, and care exercised in its administration. The people, the industry and the administrative officials of your State have reason to be proud of this important and very desirable accomplishment. Unquestionably, the strict adherence to the principles of conservation in all phases of oil and gas development and operations will serve alike the best interests of those engaged in the industry and of the public.
>
> The especially noteworthy features of your regulation of oil and gas development and production operations under the Arkansas Law are (*a*) the distinct progress realized in the elimination of unnecessary drilling units, by provision for enforced integration of small and irregular tracts into a single drilling unit, and through sound allocation of production, (*b*) the progress made in the proper regulation of the total rate of production of fields to within the range of efficient sustained production rates for the particular fields, (*c*) the allocation of the total production allowed the pool among the various properties and wells on a reasonable and equitable basis designed to prevent reasonably avoidable drainage between units or tracts, and (*d*) the complete rejection of the individual well or some expression of its potential as the unit of allocation or as the sole or major factor in the allocation of production among tracts.

Acknowledgments

Production data on controlled fields were obtained from the records of the Arkansas Oil and Gas Commission. Other production data were furnished by Warren B. Weeks, District Geologist, Phillips Petroleum Co., B. Peters, Chief Scout, Carter Oil Co., and J. C. Thompson, Geologist, Root Petroleum Company.

Developments in the California Oil Industry during the Year 1941

By V. H. Wilhelm,* Member A.I.M.E.

The year 1941 in the California oil industry was marked by an increased market demand, drilling activity, and production of crude oil.

Although seven new oil fields and two gas fields were discovered during the year, additions to reserves from these discoveries, as well as extensions and revaluations of previous discoveries, were approximately 100 million barrels, as against estimated withdrawals of 230,233,000 barrels.

The year was remarkable for the very great increase in domestic demand for all products, which more than compensated for the loss in shipments to Japan, which averaged 60,041 bbl. per day during 1940.

Demand in terms of crude during 1941 was 648,967 bbl. per day as against 632,647 for the same period in 1940. This abnormal increase in demand is due to increased industrial activity, and especially increased railroad activity.

Gasoline consumption for 1941 was 241,011 bbl. per day as against 217,744 in 1940. Demand for fuel oil increased from 259,806 bbl. per day in 1940 to 285,896 in 1941, and caused a withdrawal from stocks of more than 7,473,000 barrels.

During 1941, total oil storage declined 9,153,000 bbl., but additions to storage of 1,754,000 bbl. of light oil and light oil products were offset by a withdrawal of 10,907,000 bbl. of heavier products.

Production during the year is estimated at 230,233,000 bbl. as against 222,784,386 bbl. for 1940.

Transportation

For a short time, California was affected by lack of transportation due to the diversion of tankers. This shortage affected the movement of oil from the San Joaquin Valley to the refineries, since a large percentage of this production is moved to the coast through pipe lines, and thence by tankers to Los Angeles and San Francisco. Return of the tanker fleet, which may be temporary, indicates that there is a possibility of ample supplies of petroleum products in the Pacific Northwest.

Drilling Activity

Contrary to general opinion, drilling activity increased in 1941 over the previous year, 942 wells being completed in 1941 as against 890 in 1940, an increase of 6 per cent. This increase was due to the increased demands for fuel oil, and also to the decreased drilling costs, which made many former marginal locations economic. The main activity caused by increased demands for fuel oil was in the Mt. Poso, McKittrick, Midway and Santa Maria Valley oil fields. Dry-hole footage in 1941 was 655,354 ft. as against 583,537 ft. for 1940.

Curtailment

Voluntary curtailment succeeded in holding production considerably below demand, although it was above the state quota. During the year the top allotment

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The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

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to new wells was dropped from 148 bbl. per well per day to 139 bbl. per well per day, and the state quota was increased from 570,000 to 613,200 bbl. per day.

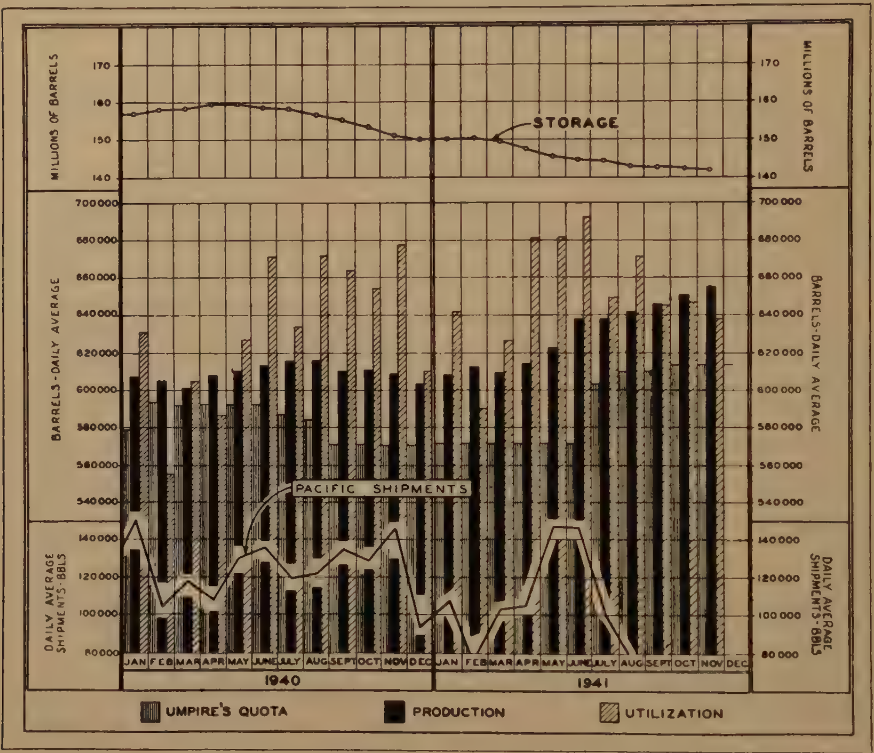

FIG. 1.—PRODUCTION, SHIPMENTS AND STORAGE OF OIL, CALIFORNIA.

A new conservation plan, approved by the Secretary of the Interior, will go into effect early in 1942. The new plan will supplant the existing uniform method of allotment. Provisions of the plan will be carried out by the Conservation Committee of California Oil Producers.

Under the new plan, desirability of the crude for defense needs will be a prime factor in allocating production to a field. Octane rating, percentage of sulphur, and the isobutane content of gas produced with oil will be considered in allocation of production. Secondarily, fields will be produced at a rate that will tend to obtain the greatest ultimate recovery. Fields from which the production can be transported only by sea will have but a very small outlet. The very great demand for heavy fuel oil will tend to eliminate this class of production from curtailment. The system is very complex and it will be difficult to predict the effect on the individual operator.

Potential of 942 wells completed during the year (Table 2) was 1,028,312 bbl., with a required allotment of 88,195 bbl. To make room for this new allotment, old wells were cut and the state quota increased.

NEW DISCOVERIES

Los Angeles Basin District

Inglewood Field.—A deep-zone extension to the Inglewood field was discovered by the Bush Oil Co. in the completion of a

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1941	During 1941
	SAN JOAQUIN VALLEY				
1	Buena Vista, *Kern*	1909	22,000	282,146,913	5,330,111
2	Belridge, North, *Kern*	1912	1,930	43,662,289	3,422,782
3	South, *Kern*	1911	2,320	23,083,090	758,359
4	Canal, *Kern*	1937	940	6,582,868	1,815,892
5	Coalinga, East, *Fresno*	1900	6,400	221 405,944	2,667,902
6	West, *Fresno*	1900	11,370	146,303,115	1,849,452
7	Nose, *Fresno*	1938	2,800	13,220,731	6,326,273
8	Northeast, *Fresno*	1939	1,340	5,078,270	3,233,190
9	Coles Levee, *Kern*	1938	2,930	8,834,118	5,711,713
10	Edison, *Kern*	1934	1,355	8,320,183	988,885
11	Elk Hills, *Kern*	1919	10,000	157,737,405	3,491,581
12	Fruitvale, *Kern*	1928	2,050	24,350,850	2,048,891
13	Greeley, *Kern*	1936	1,900	6,445,745	2,468,719
14	Helm, *Kern*	1941		2,452	2,452
15	Jacalitos, *Kern*	1941		3,231	3,231
16	Kern Front, *Kern*	1925	3,975	47,561,269	2,093,609
17	Kern River, *Kern*	1899	6,700	277,687,159	1,742,372
18	Kettleman, Middle, *Kern*	1932	200		
19	Kettleman, North, *Kern, Fresno*	1928	16,720	252,198,504	13,970,431
20	Lost Hills, *Kern*	1910	2,560	51,311 214	1,265,805
21	McKittrick, *Kern*	1887	1,525	92,371,231	1,400,821
22	Midway-Maricopa, *Kern*	1901	32,480	630,285,045	12,095,243
23	Mountain View, *Kern*	1933	2,430	40,381,380	2,137,248
24	Mt. Poso District, *Kern*	1926	3,775	58,292,327	4,505,452
25	Paloma, *Kern*	1939	2,930	208,942	56,415
26	Raisin City, *Fresno*	1941	300	61,531	61,531
27	Richfield Western, *Kern*	1938	2,000	Included with Coles Levee	
28	Rio Bravo, *Kern*	1937	2,140	12,721,813	4,483,665
29	Round Mountain, *Kern*	1927	1,710	30,737,825	2,785,958
30	Shafter, *Kern*	1941		13,589	13,589
31	Strand, *Kern*	1939	320	1,215,354	547,254
32	Ten Sections, *Kern*	1936	2,260	15,585,451	5,232,152
33	Wasco, *Kern*	1938	360	1,724,873	630,859
34	Wheeler Ridge, *Kern*	1922	300	3,920,590	104,028
35	Others			946,430	97,770
36	San Joaquin, total		150,020	2,464,401,731	93,343,635
	COASTAL DISTRICT			80,575,099	1,978,471
37	Capitan, *Santa Barbara*	1929	296	5,646,933	740,309
38	Elwood, *Santa Barbara*	1928	480	68,415,654	1,159,385
39	Santa Barbara, *Santa Barbara*	1929	165	3,354,140	74,218
40	Summerland, *Santa Barbara*	1894	180	3,158,372	4,559
	SANTA MARIA DISTRICT			169,067,077	10,006,070
41	Casmalia, *Santa Barbara*	1904	1,010		130,482
42	Cat Canyon, *Santa Barbara*	1908	1,430		350,567
43	Gato Ridge, *Santa Barbara*	1931	440	5,579,611	1,377,735
44	Lompoc, *Santa Barbara*	1903	4,223		161,428
45	Orcutt, *Santa Barbara*	1903	4,220		1,137,316
46	Santa Maria Valley, *Santa Barbara*	1934	5,610	22,149,509	6,848,542
	VENTURA DISTRICT			260,318,065	15,840,861
47	Padre Canyon, *Ventura*	1936	180	1,706,882	366,024
48	Rincon, *Ventura*	1927	425	14,082,982	1,538,169
49	San Miguelito, *Ventura*	1931	430	5,868,030	1,063,525
50	Ventura Avenue, *Ventura*	1916	2,000	238,660,171	12,873,143
	VENTURA-NEWHALL DISTRICT			67,615,942	3,307,478
51	Bardsdale, *Ventura*	1894	287		50,765
52	Del Valle, *Los Angeles*	1940	370	726,622	695,931
53	Elsmere Canyon, *Los Angeles*	1889	230		
54	Ex-Mission, *Ventura*	1875	130		12,102
55	Hopper Canyon, *Ventura*	1887	153		44,855
56	Modelo, *Ventura*	1898	60		4,057
57	Newhall Potrero, *Los Angeles*	1937	400	2,274,790	998,103
58	Oak Canyon, *Los Angeles*	1941	240	47,815	47,815
59	Oxnard, *Ventura*	1937	490		77,914

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil			
				During 1941		End of 1941			Number of Wells								
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average			Sulphur, Per Cent
1	With Midway-Maricopa			5	0	241	656			656				29	22	26.6	0.59
2	299,887	43,428		9	0	58	66		44	22	4,150			42	28	34.5	0.25
3						34	231		2	229				26	14	24	
4	With Strand					6	32		17	15	3,500	3,250		38	36	37.5	
5	18,239	8,036				384	215			215				22	19	21.0	0.67
6				2	9	88	628			628				23	12	15.8	0.45
7				44	2	3	138		133	5	3,400			34	28	33	
8				23	0	1	72		68	4	3,750			54	27	28	
9	18,645	14,044		43	0	16	104		101	3	4,200		PM	34	28	33	
10	With Mt. View			11	0	7	108		5	103				26	15	18.5	
11	80,411	1,653		9	0	131	128		2	126				25	15	22.1	0.57
12				1	0	18	163			163				24	14	19.8	0.60
13	16,957	1,861		28	0	2	66		56	10	3,000-Greeley 4,850-Vedder			60	32	38.5	0.28
14				1	0		1		1	0						65	
15				1	0		1			1						40	
16				13	0	21	441			441				15	12	14.4	
17				15	0	591	1,682			1,682				14	12	13.3	1.07
18	14,065					1								58	48	55.1	
19	1,490,557	93,424		20	6	56	266		96	170	3,150-Temblor 4,650-Eocene			37	34	36.5	0.30
20		475				42	356		1	355				36	13	18	0.99
21				8	0	88	243		1	242				22	12	14.2	1.02
22	375,590	12,368		9	0	583	2,160			2,160				28	12	17.5	0.75
23	48,988	1,649				13	163		8	155				31	20	26	0.66
24				65	0	59	418			418				15	12	13.8	
25				2	0	5	2		2	0	4,750			48	55	51	
26				7	1	1	6		6	0				36	24	30	
27											4,000			33	45	40	
28	12,987	6,006		25	0	1	96		94	2	4,850			40	37	38.5	
29				10	0	21	222			222				17	13	16.5	
30				1	0		1		1	0						37	
31	6,711	3,683		3	0	1	12		11	1				35	38	35	0.37
32	23,281	7,055		36	0	7	112		83	29	3,550			38	34	35.4	
33				1	0		13		13	0	5 650					38	
34							34			34				23	24	23.5	
35		1,668		14	0	21	24		2	22							
36		195,350		406	18	2,500	8,860		747	8,113							
37	3,514	437		5	0	5	53			53				43	18	28	
38	63,060	2,214		1	5	21	61		4	57				41	22	33.7	
39				1	3	3	21			21				19	14	17	0.30
40				0	3	1	3			3				19	17	18	0.54
41				0	1	58	7			7				21	8	10.3	2.84
42				3	1	62	11		1	10				16	10	13.5	4.13
43						5	15			15				14	13	13.9	
44				0	1	24	11		2	9				21	20	20.5	4.4
45				3	0	80	150			150				26	18	22.6	2.63
46		3,307		56	2	20	194		46	148	1,750			17	13	15.9	
47	17,086	2,461		5	0		19		5	14	2,150			31	28	29.1	
48				6	3		78		10	68				31	27	30	
49	7,588	1,290		4	0		24		23	1				34	29	30	
50	810,874	32,927		39	3	131	329		157	172	2,750			50	12	30	0.73
51				0	9	9	26		1	25				33	22	32.1	0.83
52				56	0		12		11	1	2,700					32	
53				0	0	9								23	14	16	0.70
54				0	0	1	23			23				28	18	25.2	0.72
55				0	0	2	12			12				31	18	29	
56				0	0	5	11			11				26	26	26.1	
57				25	0	1	25		24	1	3,200			35	33	33.3	
58							3		1	2							
59				0	23	1	2			2				8	8	8	

[c] Footnotes to column heads and explanation of symbols are given on page 250.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Aver. Bottoms Prod. Wells	Net Thickness, Avg. Ft. Sand	Structure[h]	Name	Depth of Hole Ft.
1	San Joaquin clay, Etchegoin	Pli	S	25	2,665	3,500	50	A	Miocene	14,622
2	Etchegoin, Temblor, Vaqueros	Pli, Mio	S	15	4,917	7,152	625	A	Cretaceous	10,800
3	Etchegoin, Temblor	Pli, Mio	S		800	874	50	A	Miocene	11,377
4	Stevens	Mio	S	20	8,250	8,297	160	A	Miocene	13,400
5	Etchegoin, Temblor	Pli, Mio	S	25	1,860	2,076	170	AUP	Cretaceous	9,418
6	Etchegoin, Sta. Margarita	Pli, Mio	S		900	1,580	180	MUP	Cretaceous	4,883
7	Avenal	Eoc	S	22	6,400	7,440	360	MU	Eocene	8,416
8	Avenal	Eoc	S	25	7,980	8,226	130	MU	Cretaceous	9,614
9	Stevens	Mio	S	24	8,070	9,621	200	MU	Miocene	10,101
10	Kern River, Temblor	Pli, Mio	S		2,000	2,239	125	MU	Granite	800
11	San Joaquin clay, Etchegoin, Stevens	Pli, Mio	S	38	2,600	3,115	75	A	Miocene	11,177
12	Etchegoin, Chanac	Pli	S		3,000	3,685	88	MU	Schist-Jurassic	8,531
13	Stevens, Vedder	Mio	S	22	11,430	11,500	290	AM	Lower Miocene	12,504
14	Temblor, Eocene	Mio, Eoc	S		7,300	8,005	90	A	Cretaceous	10,257
15	Temblor	Mio, Eoc	S		3,865	3,905	11	AF	Cretaceous	6,031
16	Etchegoin	Pli	S			2,175	80	MF	Miocene	2,650
17	Kern River	Pli	S		400	837	130	MU	Oligocene	4,852
18	Temblor	Mio	S		7,250	7,285	57	A	Miocene	9,138
19	Temblor, Avenal	Mio, Eoc	S	16	6,300 10,200	8,236 10,851	850	A	Cretaceous	12,884
20	Etchegoin	Pli	S		1,170	1,204	80	A	Miocene	7,858
21	Etchegoin	Pli	S		800	1,107	350	MUF	Miocene	6,664
22	Etchegoin, Maricopa	Pli, Mio	S		1,950	2,095	65	MUF	Miocene	10,410
23	Chanac, Sta. Margarita	Pli, Mio	S		6,080	6,165	55	MF	Granite	8,624
24	Vedder	Mio	S	35	1,600	1,745	150	MF	Granite	3,130
25	Stevens	Mio	S	20	10,140	10,376	200	A	Miocene	11,811
26		Mio	S		5,040	5,090	10	A	Eocene	6,429
27	Stevens	Mio	S	24	8,990	9,580	300	MU	Miocene	10,120
28	Vedder	Mio	S		11,249	11,495	220	A	Schist-Jurassic	14,108
29	Jewett, Vedder	Mio	S	34		1,861	66	MF	Oligocene	6,070
30	Vedder	Mio	S		12,800	12,890		A	Miocene	12,934
31	Stevens	Mio	S		8,320	8,432	110	D	Miocene	12,818
32	Stevens	Mio	S	22	7,850	8,216	200	A	Miocene	10,023
33	Vedder	Mio	S	28	13,100	13,143	32	A	Eocene	15,004
34	Etchegoin, Sta. Margarita	Pli, Mio	S	28	2,000	2,717	4	A	Oligocene	11,204
35										
36										
37	Vaqueros, Sespe	Mio, Olig	S		1,150	1,400 2,734	135	AF	Sespe	4,071
38	Monterey, Vaqueros, Sespe	Mio, Olig	S	25	2,800	3,128 3,906	330	AF	Eocene	7,151
39	Vaqueros	Mio	S		1,960	2,003	75	MF	Sespe	4,730
40	Pliocene, Vaqueros	Pli, Mio	S		400	1,600	225	A	Sespe	5,041
41	Sisquoc, Monterey	Mio	H		1,200	1,679	Fis	A	Miocene	3,900
42	Sisquoc	Mio	S & H		2,000	3,000	Fis	A	Cretaceous	7,199
43	Sisquoc, Monterey	Mio	H		1,800	3,255	Fis	AF	Vaqueros, Miocene	6‘510
44	Sisquoc, Monterey	Mio	S & H		2,200	2,711	Fis	A	Miocene	4,310
45	Sisquoc, Monterey	Mio	S & H		1,100	3,175	Fis	A	Sespe-Oligocene	5,915
46	Monterey	Mio	S & H		4,000	4,488	Fis	MU	Franciscan	8,133
47	Pico, Repetto	Pli	S		4,800	5,872	140	AF	Miocene	6,566
48	Pico, Repetto	Pli	S		2,500	4,000	140	A	Pliocene	10,515
49	Pico, Repetto	Pli	S		5,500	7,042	680	AF	Pliocene	10,030
50	Pico, Repetto	Pli	S		3,400	6,244 7,188 9,240	3,000	A	Pliocene	11,516
51	Sespe, Tejon	Olig, Eoc	S		500	888	y	A	Eocene	6,804
52	Modelo	Mio	S	28	6,037	6,954	107	A	Miocene	7,800
53	Pico, Repetto	Pli	S		240	800	y	MU	Jurassic schist	2,117
54	Repetto	Pli	S		500	1,585	y	MF		
55	Modelo	Mio	S		1,500	1,828	y	A		2,200
56	Modelo	Mio	S		180	2,050	y	A		1,488
57	Modelo	Mio	S		6,160	6,917	230	AF	Miocene	7,832
58							110		Miocene	8,090
59	Modelo	Mio	S		2,100	2,905	y	MU	Miocene	4,285

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1941	During 1941
60	Pico Canyon-Newhall, *Los Angeles*	1875	110		32,033
61	Sespe, *Ventura*	1887	289		86,245
62	Shiells Canyon, *Ventura*	1911	510		374,552
63	Simi, *Ventura*	1912	635		29,932
64	Sisar-Silverthread, *Ventura*	1885	330		41,266
65	South Mountain, *Ventura*	1916	785		526,958
66	Sulphur Mt., *Ventura*	1927	40		2,560
67	Tapo-Eureka, *Ventura*	1882	224		9,296
68	Temescal, *Ventura*	1924	120		201,652
69	Timber Canyon, *Ventura*	1885	110		8,974
70	Fresno-Lion Mt., *Ventura*	1917	50		6,972
71	Torrey Canyon, *Ventura*	1896	140		53,535
72	Wiley-Towsley Canyon, *Los Angeles*	1887	28		1,961
	OTHER COASTAL COUNTIES			1,262,341	25,338
73	Edna, *San Luis Obispo*	1929	25	741,702	5,449
74	Pismo, *San Luis Obispo*	1928	200	104,445	7,607
75	Half Moon Bay, *San Mateo*	1886	80	41,477	614
76	Sargent-Los Gatos, *Santa Clara*	1886	60	374,717	11,668
77	Coastal District total		27,175	578,838,524	31,158,218
	LOS ANGELES BASIN				
78	Alamitos, *Los Angeles*	1931	200	24,140,238	397,084
79	Aliso, *Los Angeles*	1938	296	1,708,564	952,603
80	Brea Olinda, *Orange*	1889	1,680	167,893,925	2,050,580
81	Coyote, East, *Orange*	1911	1,160	43,596,352	1,379,162
82	Coyote, West, *Orange*	1909	985	125,446,502	3,070,608
83	Dominguez, *Los Angeles*	1923	1,200	130,254,351	8,478,083
84	El Segundo, *Los Angeles*	1935	930	10,136,608	521,446
85	Huntington Beach, *Orange*	1920	2,200	301,011,225	10,692,377
86	Inglewood, *Los Angeles*	1924	1,075	125,694,085	4,890,688
87	Lawndale, *Los Angeles*	1928	72	1,070,600	10,313
88	Long Beach, *Los Angeles*	1921	1,600	663,664,354	14,516,548
89	Los Angeles District, *Los Angeles*	1892	1,627	66,031,823	187,546
90	Montebello, *Los Angeles*	1917	1,750	127,249,461	4,859,586
91	Playa del Rey, *Los Angeles*	1934	670	47,488,128	1,288,072
92	Potrero, *Los Angeles*	1928	220	4,276,660	709,616
93	Richfield, *Orange*	1919	1,370	92,120,961	2,476,671
94	Rosecrans-Athens, *Los Angeles*	1924	850	48,182,337	3,433,964
95	Santa Fe Springs, *Los Angeles*	1919	1,630	477,174,924	8,536,874
96	Seal Beach, *Los Angeles*	1926	310	65,695,085	2,022,102
97	Torrance, *Los Angeles*	1922	6,200	104,224,024	3,154,639
98	Whittier, *Los Angeles*	1898	600	18,418,069	172,242
99	Wilmington, *Los Angeles*	1935	4,400	140,021,211	30,542,409
100	Others			3,037,405	245,370
101	Los Angeles Basin total		31,025	2,788,536,892	104,588,580
102	STATE TOTAL			5,831,777,147	229,090,433

GAS FIELDS

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		
	NORTHERN GROUP		Gas^b		B.t.u.
103	Eureka, *Humboldt*	1937	520		1,040
104	McDonald Island, *San Joaquin*	1936	1,900		980
105	Potrero Hills, *Solano*	1938	100		991
106	Rio Vista, *Sacramento, Solano*	1936	24,900		1,040
107	Sutter Buttes, *Sutter*	1936	200		1,000
108	Tracy, *San Joaquin*	1935	620		935
109	Willows, *Glenn*	1938	240		990
110	Fairfield Knolls, *Yolo*	1937	160		945
111	Petaluma, *Sonoma*	1941	40		1,002
112	Vernalis, *San Joaquin*	1941	200		
	SAN JOAQUIN VALLEY				
113	Buena Vista Lake, *Kern*	1934	750		1,000
114	Buttonwillow, *Kern*	1926	1,700		985
115	Chowchilla, *Madera*	1935	300		930
116	Trico, *Kern*	1935	7,480		980
117	Semitropic, *Kern*	1932	3,800		980
	COASTAL AREA				
118	Goleta, *Santa Barbara*	1929	200		1,055

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil			
				During 1941		End of 1941			Number of Wells					Gravity A.P.I. at 60°F., Weighted Average			Sulphur, Per Cent
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941					
60				0	0	37	23			23				38	35	37.3	
61				0	3	13	22			22				32	19	20.6	
62	With So. Mt.					16	120		1	119				36	28	35.1	
63				0	2	63	47			47				32	16	28.1	0.68
64						7	68			68				24	15	18.5	
65	65,286	3,635				7	91			91				28	20	23.9	1.73
66							1			1				16	15	15.5	
67							21			21				24	21	22.4	
68							13			13				24	21	22	
69							8			8				34	25	28.7	
70							17			17				23	20	22	
71						3	38			38				28	27	27.5	
72						9	4			4				27	20	23.6	
73						2	15			15				14	13	13.3	
74						4	2			2						22	
75						13										54	
76						14	9			9						13	0.86
77		46,271		157	59	626	1,589		286	1,303							
78						1	38		1	37				28	16	26.8	
79				4		1	15		11	4	2,250 3,800			54	23	24	
80	58,368	1,419		2	1	113	309			309				32	14	22.5	0.97
81	51,783	2,354		6	7	21	111		1	110			SR	26	18	25	1.46
82				4		83	77		5	72			RP	31	24	28.9	
83	215,105	15,426		48	3	35	267		66	201				35	28	30.4	0.85
84	7,427	261			5	5	40			40				29	15	21.8	
85	309,021	9,685		53	25	103	630		28	602				27	11	23.5	1.30
86	93,110	4,348		18	2	103	207		32	175	4 450 (sentous)			38	14	22.0	
87							3			3				29	23	25.9	
88	870,232	12,933		26	70	24	1,237			1,237				32	12	25.0	1.25
89					20		93			93				18	13	13.7	1.0
90	98,249	17,583		2	8	57	337		23	314	3,700 (west)			39	13	30.0	0.79
91	49,455	955			16	3	144			144				24	11	21.0	2.7
92				3		1	23		7	16				48	33	44.0	
93	84,964	2,391		2	2	4	304			304				29	14	20.5	1.60
94	120,950	10,822		12	7	10	182		18	164				42	31	33.0	0.48
95	673,100	7,232		3	18	64	574			574				38	28	32.5	0.40
96	100,143	3,105		5	1	21	82		10	72				29	10	23.0	
97	76,819	2,867		20	60	43	627			627				27	13	22.0	1.62
98				1	1	35	143			143				30	14	19.0	0.77
99	91,524	26,800		167	2	23	1,059		467	592	1,350 (Ranger) 2,000 (Ford)			28	13	21.0	2.5
100	4,023	3,473		2		30	44			44							
101		121,654		378	248	780	6,546		669	5,877							
102				941	325	3,906	16.995		1,702	15,293							

GAS FIELDS

Line Number	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941	Repressuring Operation[d]				Sulphur, Per Cent
103	183	77	3	0	0			1			2,488						
104	35,565	9,541	7	1	0			6			2,300						
105			1	0	0												
106	35,752	15,808	45	17	1			40			1,717	1,650					
107	4,082	1,522	4	0	0			3			2,950						
108	9,510	535	6	0	0			4			1,800	1,100					
109			1	0	0												
110			2	0	0			2			1,450						
111			1	0	0												
112			2	2	0			2									
113	3,702	282	6	0	0			4			1,260	650					
114	20,853	2,673	27	0	0			18									
115			3	0	0			3									
116	9,692	3,142	21	0	0			15			1,140						
117	4,440	739	22	0	0			3			1,110	900					
118			5	1	0			5			1,800	1,450					

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
					Depth, Avg. Ft.					
	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Aver. Bottoms Prod. Wells	Net Thickness, Avg. Ft. Sand	Structure[h]	Name	Depth of Hole, Ft.
60	Modelo	Mio	S		858	1,611	y	A	Eocene	4,300
61	Sespe	Olig	S		400	1,651	y	A & S	Oligocene	3,595
62	Sespe	Olig	S		100	2,000	640	A	Eocene	7,428
63	Meganos	Eoc	S		1,100	1,213	y	A		3,934
64	Sespe	Olig	S		315	683	y	MF		
65	Sespe	Olig	S		2,200	3,362	956	A	Eocene	6,702
66	Modelo	Mio	S		2,000	2,500	Fis	ML		
67	Modelo, Sespe	Mio, Olig	S		500	995	y	A		2,956
68	Modelo	Mio	S		2,000	2,411	y	A	Miocene	4,584
69	Repetto, Modelo	Pli, Mio	S		300	2,605	y	MF	Miocene	3,300
70	Modelo	Mio	S		844	1,044	y	ML	Miocene	
71	Vaqueros, Sespe	Mio, Olig	S		700	1,363	y	AF	Miocene	2,500
72	Modelo	Mio	S		600	1,016	y	AF	Miocene	4,400
73	Monterey	Mio	H		800	1,200	y	A & S	Jurassic schist	2,125
74	Monterey	Mio	H			2,900	y	S		
75	Purissima, Monterey	Pli, Mio	S, H		1,379	1,600	y	ML	Miocene	7,982
76	Monterey	Mio	S, H		900	1,500		AF	Miocene	
77										
78	Pico, Repetto, Puente	Pli, Mio	S		4,635	5,810	250	AF	Miocene	9,054
79	Pico, Repetto, Modelo	Pli, Mio	S		4,795	5,287	170	M	Miocene	9,291
80	Repetto, Puente	Pli, Mio	S		260	3,026	800	AF	Miocene	8,021
81	Repetto, Puente	Pli, Mio	S		2,450	3,607	153	AF	Miocene	9,084
82	Repetto	Pli	S		2,800	4,471	473	D	Miocene	8,144
83	Repetto, Puente	Pli, Mio	S	28	3,800	5,189	1,800	AF	Miocene	12,720
84	Puente, Franciscan	Mio, Jur	S Fis		6,890	7,316	50	A AF	Franciscan schist	8,009
85	Repetto, Puente	Pli, Mio	S	33	1,900	4,009	1,200	MF	Miocene	9,054
86	Pico, Repetto, Puente, Monterey	Pli, Mio	S		1,073	2,597	975	AF	Miocene	10,598
87	Puente	Mio	S		6,375	5,841	9	MU	Miocene	7,405
88	Pico, Repetto, Puente	Pli, Mio	S	30	2,377	5,264	1,650	AF	Miocene	10,720
89	Repetto, Puente	Pli, Mio	S		475	1,045	9	AF	Miocene	5,074
90	Repetto, Puente	Pli, Mio	S		1,730	4,422	800	A	Miocene	9,334
91	Repetto, Puente, Franciscan	Pli, Mio Jur	S Fis		3,350	5,371	200	A	Franciscan schist	7,048
92	Pico, Puente, Franciscan	Pli, Mio	S	29	3,640	5,605	350	AF	Miocene	9,923
93	Puente	Pli	S		2,900	4,057	510	A	Oligocene, Sespe	10,496
94	Repetto, Puente	Pli, Mio	S	22	4,035	6,150	1,050	AF	Miocene	10,389
95	Repetto, Puente	Pli, Mio	S	29	3,470	5,373	1,360	D	Miocene	11,314
96	Repetto, Puente	Pli, Mio	S		4,314	5,441	350	AF	Miocene	9,054
97	Puente	Mio	S	27	2,637	4,220	120	AF	Franciscan schist	6,957
98	Repetto, Puente	Pli, Mio	S		200	2,109	270	MUF	Miocene	5,040
99	Repetto, Puente	Pli, Mio	S	28	2,320	3,631	420	AF	Franciscan schist	6,814
100						2,314				
101										
102										
	GAS FIELDS									
103	Repetto	Pli	S & H	26	3,800	4,900	170	A	Pliocene	7,708
104	Capay	Eoc	S	35	5,178	5,216	38	D	Cretaceous	8,810
105	Cretaceous	Cre	S		3,235	3,265	30	D	Cretaceous	5,334
106	Domingine, Ione	Eoc	S	35	3,800	4,344	200	AF	Cretaceous	7,029
107	Cretaceous	Cre	S		2,700	5,855	87	MU	Igneous rock	6,900
108	Cretaceous	Cre	S	28	3,926	4,070	65	D	Cretaceous	9,690
109	Cretaceous	Cre	S		2,345	2,360	10	D	Cretaceous	6,014
110	Cretaceous	Cre	S		3,651	3,682	30	A	Cretaceous	5,185
111	Miocene	Mio	S		1,183	1,215	30		Miocene	1,215
112	Cretaceous	Cre	S		3,840	3,872	30	A	Cretaceous	3,873
113	Etchegoin	Pli	S		4,117	5,219	20	AF	Miocene	11,186
114	Etchegoin	Pli	S		2,500	2,750	18	D	Pliocene	4,946
115	Eocene and Cretaceous	Eoc			2,611	2,923	60			
		Cre	S		7,900	8,125	140	D	Cretaceous	8,377
116	Etchegoin	Pli	S	28	2,420	3,150	20	A	Miocene	11,468
117	Etchegoin	Pli	S	25	2,275	3,215	6	A	Miocene	9,700
118	Vaqueros	Mio	S		4,139	4,533	354	AF	Eocene	6,912

small well from sandy lenses in shale of middle Miocene (Monterey) in 1940. Further development during 1941 indicates that this deep zone, which is unconformable with and underlies only a small portion of the Pliocene producing area of the oil field, is a southwest-dipping monocline closed by a large northeast-dipping overthrust, which duplicates from 200 to 500 ft. of beds. The new zone contains an average net sand thickness of 100 ft. and has an exceptional bottom-hole formation pressure of 4500 lb. at a depth of 8300 ft. The estimated productive area is 180 acres. Because of complicated faulting, production from this new deep zone has been very erratic; large producers are offset by very small flowing wells.

Turnbull Canyon.—A small field north of the Whittier fault in Turnbull Canyon, 3 miles northeast of Whittier, was discovered by the Continental Oil Co. by the completion of Community No. 1, pumping 275 bbl. of 20° gravity oil. The structure, a faulted anticline, was discovered by surface geology and confirmed by reflection seismograph. Production is from 50 ft. of sandy lenses in upper Miocene (Puente) shale. The estimated maximum productive area is 100 acres.

Wilmington.—The Wilmington field continued as the most active in the state, completing 172 wells during the year. The potential of this field, the largest in the state, is 756,000 bbl. per day from 1085 wells, though the normal sustained capacity of the field is probably only 25 per cent of the potential.

Coastal District

Del Valle Field.—The Del Valle field, near Newhall, which was the only oil field discovered in 1940, was extended 1½ miles west by the completion of Jasper Petroleum Company's Videgain No. 1, at a depth of 5994 ft. for 450 bbl. per day of 31.5° gravity oil. The proven area of this field is now 370 acres, with a net average production-sand thickness of 110 ft. The structure of the field is an elongated plunging anticline, sealed on the north by a south-dipping fault. Lenticular sands or minor faulting may form the trap on the west side of the field.

Oak Canyon Field.—Western Gulf Oil Co. discovered the Oak Canyon field by the completion of Lechler No. 1, at a depth of 2415 ft. for 100 bbl. of 22.9° gravity oil on the pump. Western Gulf discovered a second sand by the completion of Lechler No. 2 at a depth of 6940 ft. flowing at the rate of 30 bbl. per hour of 31.5° gravity oil. This field is 2 miles northwest of the Del Valle field. The structure is a plunging anticline sealed by a fault up the pitch. The estimated productive area is 120 acres with 55 ft. of net sand.

TABLE 2.—*California Oil-field Development*

Year	Number Drilling Notices Filed	Number Drilling Wells Abandoned	Number Producers Abandoned	Number Producers Completed (New Wells)	Percentage of Increase or Decrease	Initial Production of New Wells, Daily Average, Bbl.	
						Per Well	Total
1931	329	238	177	246	−67	1,481	364,434
1932	279	191	172	184	−25	852	156,823
1933	596	163	215	248	+35	1,105	274,104
1934	631	247	200	449	+81	1,190	534,508
1935	986	347	203	710	+37	954	677,320
1936	1,102	320	208	786	+11	471	370,227
1937	1,643	313	273	1,156	+47	560	647,331
1938	1,162	265	252	994	−14	1,242	1,234,482
1939	1,174	251	274	851	−14	1,314	1,118,102
1940	1,042	156	330	890	− 5	1,428	1,270,756
1941	1,210	192	301	942	+ 6	1,092	1,028,312

San Joaquin Valley

Dyer Creek.—The Shell Oil Co. discovered a small fault-line accumulation north of the Mt. Poso field by the completion on the pump of its Smith No. 56 *X* 11, from a depth of 2361 ft. for 163 bbl. of 15.2° gravity oil. Production is from the Vedder zone of Miocene age. The second well drilling in this new area was a dry hole, therefore it is estimated that not over 40 acres will prove productive.

Union Avenue.—In the Union Avenue area, adjacent to the city of Bakersfield, the Hancock Oil Co. completed Roberts No. 1, for 100 bbl. of 15.4° gravity oil on the pump. Production is coming from thin sandy lenses in the Santa Margarita shale of upper Miocene age. The structure is monoclinal, sealed by the western extension of the Mountain View fault. Productive area is very limited; a direct offset failed to obtain production but later was whipstocked into the productive area.

Coalinga (*Nose and Northeast*).—Development has shown that these two fields are one structure, a narrow shore-line deposit flanking the old East Coalinga field. The field is almost drilled up, and has next to the highest potential of any field in the state, 712,288 bbl. from 216 wells, with a total proven area of 4200 acres and a net average sand thickness of 288 feet.

Raisin City.—The Shell Oil Co. discovered the Raisin City field, southwest of Fresno, in an entirely new productive area in California. For many years it has been a common prediction that no commercial oil production would be found north of the Coalinga field, but the Shell company discovery has refuted this prophecy. A very active leasing and drilling campaign in the northern San Joaquin Valley followed the discovery and has resulted in the discovery of two additional fields. The discovery well, which was a deep test to the Eocene and made formation tests of a thin oil sand in the Santa Margarita (upper Miocene), was completed as a gas well, producing 6750 M cu. ft. of gas from a depth of 5045 ft. Production of gas is from the Temblor (Miocene). Average thickness of the gas sand is 15 feet.

The second well, Shell Inc. Santa Ana and Fresno Land Co. No. 1–19, was completed as an oil well, flowing 743 bbl. per day, 24° gravity, through a $^{22}/_{64}$-in. bean. Production is from 20 ft. of fine floating sand showing very little gas.

Discovery of this field was made by reflection seismograph. Dips of the formation are very low and areal extent is unknown. The productive area is estimated to be 420 acres.

Jacalitos Dome.—The Jacalitos dome, south of Coalinga and west of Kettleman Hills, which is a well-defined structure on the surface, and which has been drilled at various intervals since 1900, has at last become a producing field, mainly by application of modern methods of drilling and completion. All wells drilled on this structure have had interesting showings of oil at the top of the Temblor. Discovery was made by the Wilshire Annex Oil Co. on the east flank of the structure in well No. 33-26 E., sec. 26, 21 S., 15 E. The discovery well is pumping 85 bbl. of 40.3° gravity oil from a depth of 3938 ft., producing from 11 ft. of net sand. The oil, although of high gravity, has a very low octane rating. The estimated productive area is 400 acres, from a maximum of 14 ft. of colorless sand.

Helm Oil Field.—Amerada Petroleum Co. discovered a new distillate field in the Helm district of Fresno County. Three zones, one in the Eocene and two in the Miocene, have been tested, and all show the same characteristics of large volumes of gas with considerable quantities of 65° oil. The discovery well, Amerada-Clover No. 1, sec. 24, T. 16 N., R. 17 E., produced at the rate of 662 bbl. of 64.7 gravity oil, with gas at the rate of 13,680 M cu. ft.

from a depth of 8005 ft. Extent and value of the discovery are unknown.

Shafter.—Midway between the Wasco and Rio Bravo fields, the Continental Oil Co. discovered a small field by bringing in its K.C.L. C-2 in sec. 35, T. 27 S., R. 34 E., flowing at the rate of 542 bbl. per day of 36.8° gravity oil, with 550,000 cu. ft. of gas, from a depth of 12,811 ft. Production is from the Vedder zone of Miocene age. Productive sand thickness is estimated at 10 ft. and productive area not over 100 acres.

Riverdale.—During the latter part of December, the Amerada Petroleum Co. discovered a second field in the area south of Fresno by bringing in its well, Lawton No. 45-26, ½ mile west of Riverdale. The discovery well had an initial production of 558 bbl. of 34° gravity oil, from gun-shot perforations in 5½-in. casing at depths of 6665 to 6685 ft. Production is coming from the Temblor (Miocene), on a structure discovered by geophysics.

GAS FIELDS

During the year oil companies have tended to replace wasteful production of gas from gas caps in oil fields with the production of gas from dry gas fields. Renewed drilling activities in the Sacramento Valley led to the discovery of two gas fields near Sacramento. Both of these fields are considered of minor extent.

Vernalis Gas Field.—A few miles south of Tracy the Standard Oil Co. brought in its Blewett Community No. 1, sec. 25, 3 S., 6 E. M.D.M., producing 10,000,000 ft. of gas from Cretaceous formations between depths of 3840 and 3873 ft. The structure was defined by reflection seismograph.

Petaluma Field.—The Trico Oil and Gas Co. discovered a dry gas field near Petaluma, in sec. 30, 5 N., 6 W., at very shallow depths from Miocene formation. Initial production of the discovery well was 3,000,000 ft. of gas from formations between 1183 and 1215 feet.

ADVANCES IN DRILLING AND PRODUCTION PRACTICE

No world's records have been broken in California during the past several years; instead, the objective has been to reduce the costs of drilling.

It is now known that more than 11,000 ft. of open hole can be carried, providing the stratigraphic conditions are favorable and that mud and hole deviation are properly controlled. With more open hole, of smaller diameter than formerly, and less coring (not necessarily in footage, but in tons), considerable sums have been saved. At a drilling cost of $10 per foot or less, wells can now be drilled to depths exceeding 11,000 feet.

A recent departure from the usual oil-field steam plants is the large unitized generating plant, consisting of two marine-type wash-tube boilers. In conjunction there are complete facilities for condensing all of the exhaust steam for return to the boilers.

Although central boiler plants are not new, by proper foresight in the planning of the drilling of a number of wells at adjoining locations, central boiler plants can be adopted.

Mud control has become a definite practice in California. Some companies now employ "mud engineers," whose principal objectives are mud control and research. It has become almost a standard practice to handle mud in tanks, although some bulk and sacked mud is still hauled to the rig and mixed there to the required specifications. For removing sand and cuttings from the mud, one new type of screen has made its appearance—a large drum wrapped with wire, which forms fine slots.

Portable drilling rigs and derricks are constantly finding a greater range of usage in California, and are now drilling to the depths of 5000 to 7000 ft. Internal-combustion engines furnish the power in almost all of those installations.

The world's second deepest well, 14,622 ft. deep, was drilled with purchased electric power by the Honolulu Oil Corporation in the Buena Vista Hills. Originally intended for drilling to about 7000 ft., the draw works driven by two 125-hp. motors, compounded through a synchronizing gear and a 125-hp. motor driving the rotary table by a direct shaft connection, the remarkable depth indicated was reached.

Slim holes, or modified slim holes, are coming into greater use in California. The most popular size of oil string is 7 in. o.d., although in general major companies are finishing wells with 5½-in. o.d. production strings. Many strings are cemented solid on bottom and then gun-perforated for production, whereas others are combination strings with perforated section attached and cemented through perforations for water shutoff. Water shutoff is tested by gun perforating and formation testing before the baffle plate is drilled out.

Bulk cementing is becoming more and more the vogue. Quicker jobs, better slurry control, greater economy, and a saving in rig time and labor are effected thereby.

In at least two of the newly discovered fields of the year, slim holes were drilled to the maximum depth without coring. An electrical log was run and interesting sand bodies were sampled by a side-hole core device. Casing was cemented on bottom and zones that showed saturation in the wall samples were tested progressively, starting at the bottom.

Radioactive well logs in cased holes for the purpose of correlation, location of possible productive sand bodies behind casing, and obtaining accurate logs through multiple strings of casing have been introduced into California with considerable success. With improvement in the process, it will be a very valuable tool for the oil industry.

Electrical centrifugal pumps have been used in the Kern River field at shallow depths with considerable success. More than 1000 bbl. of fluid has been raised at small cost, and flooded areas have been dewatered.

CONCLUSIONS

It is difficult to predict the probable state of the industry in 1942. Increased demands for fuel oil are likely, to such an extent that maximum production may be required of heavy crude oil desirable for fuel oil and high-octane gasoline. Civilian use of gasoline will be decreased because of lack of automobiles and tire shortage. Increased drilling of wildcat wells is expected and will be encouraged. The drilling of wells that do not materially increase the reserves of an oil field will be restricted, and as wide spacing is prescribed by the office of the Oil Coordinator, probably the number of wells drilled in California in 1942 will be appreciably less than in 1941. Gasoline may become a by-product instead of a necessity. Very little new steel will be available to the industry because of defense needs.

Oil and Gas Development in Illinois in 1941

By Alfred H. Bell,* Member A.I.M.E., and George V. Cohee*

In 1941 Illinois produced 134,139,000 bbl. of oil, or 9.5 per cent of the total for the United States, and ranked fourth among the states. The production for 1941 declined 9.2 per cent from the previous year's total of 147,647,000 bbl. Daily average production for 1941 was 366,000 bbl. At the beginning of the year daily production was slightly more than 326,000 bbl. and it remained at approximately that amount until June, when there was a slight increase. The increase continued until the peak of 431,260 bbl. daily was reached for the week ending Oct. 4. Daily average production at the end of the year was approximately 387,500 barrels.

The increased production during the last half of 1941 was largely due to the rapid development of the Johnsonville field, Wayne County, the Rural Hill field, Hamilton County, and the Benton field, Franklin County—new fields discovered in the current year (Fig. 1)—and the Woodlawn pool, discovered in 1940.

DISCOVERIES

In 19 counties in southern Illinois, 44 new fields were discovered in 1941 (Fig. 2 and Table 2), and extensions to 40 fields were successfully completed (Table 3). At the end of the year there were 10,496 wells in the fields discovered since Jan. 1, 1937, as compared with 7,965 wells at the end of 1940. The area proved for production in the new fields increased from 78,040 acres at the beginning of 1941 to 97,483 acres at the end of the year (Table 1)—an increase of 19,433 acres, of which 9,955 acres are in the fields discovered during the current year, and the remainder of 9,478 acres in extensions to pools discovered earlier.

DRILLING

During the past year, 3838 wells were completed in Illinois (Table 4), of which 2912 were oil producers, 13 were gas producers and 913 were dry holes; 76 per cent of the wells drilled were producers. Of the total number drilled, 591 wells are classified as "wildcat" and of these 84 (1 in 7) were successful in obtaining production.

The results of an investigation to ascertain the reason for the locations of the wildcat wells are set forth in Table 5. Of the 591 wildcat wells, the 292 known to have been located by scientific methods were 21.6 per cent successful.

The total footage of wildcat wells drilled in 1941 was 1,341,743 ft., of which a total of 216,995 ft. was drilled in successful wells.

EXPLORATION METHODS

Subsurface geology and geophysics, largely the reflection seismograph, are still the principal methods used in exploration and development in the state. The number of seismograph parties operating throughout the year was as follows: seven parties on Jan. 1, 1941; five on Apr. 1; four on July 1; eight on Oct. 1; fifteen on Jan. 1, 1942.

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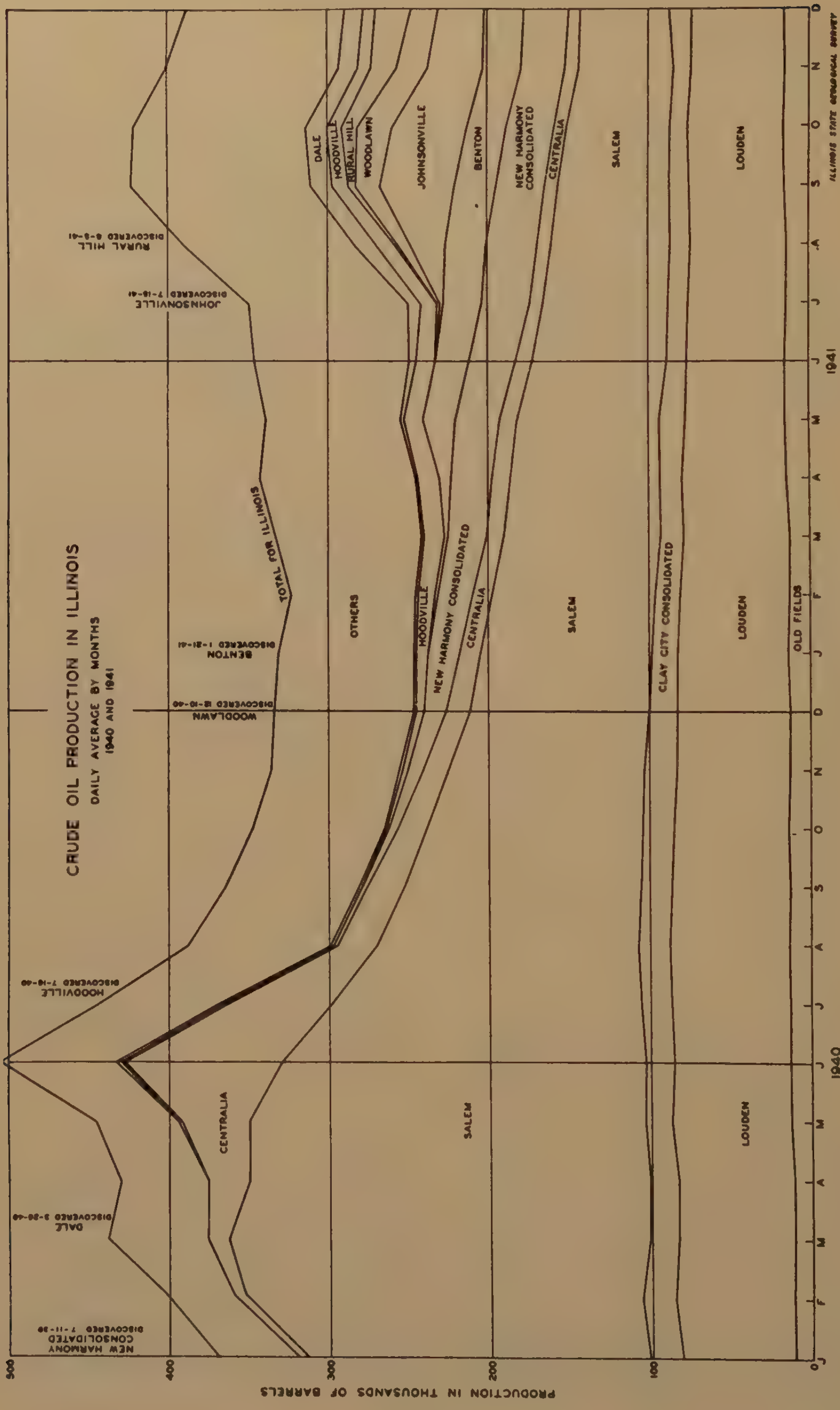
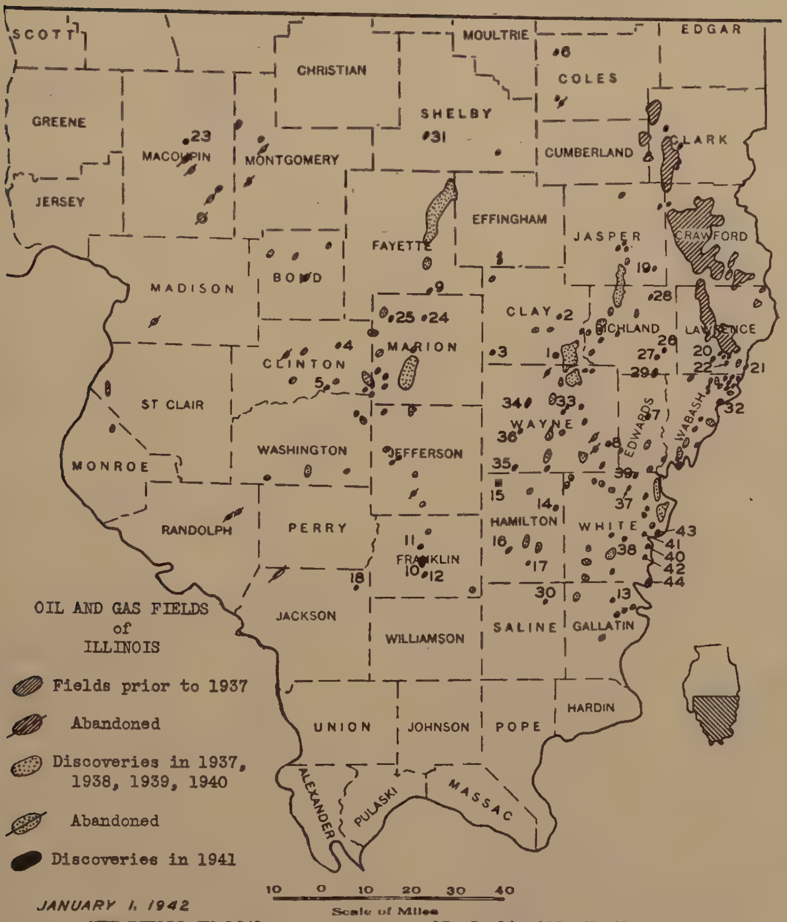

CRUDE OIL PRODUCTION IN ILLINOIS
DAILY AVERAGE BY MONTHS
1940 AND 1941
TOTAL FOR ILLINOIS
NEW HARMONY CONSOLIDATED DISCOVERED 7-11-39
DALE DISCOVERED 3-30-40
HOODVILLE DISCOVERED 7-16-40
WOODLAWN DISCOVERED 12-10-40
BENTON DISCOVERED 1-21-41
JOHNSONVILLE DISCOVERED 7-15-41
RURAL HILL DISCOVERED 6-5-41
CENTRALIA
SALEM
LOUDEN
OTHERS
HOODVILLE
NEW HARMONY CONSOLIDATED
CENTRALIA
SALEM
CLAY CITY CONSOLIDATED
LOUDEN
OLD FIELDS
DALE
HOODVILLE
RURAL HILL
WOODLAWN
JOHNSONVILLE
BENTON
NEW HARMONY CONSOLIDATED
CENTRALIA
SALEM
LOUDEN
500
400
300
200
100
0
PRODUCTION IN THOUSANDS OF BARRELS
J F M A M J J A S O N D J F M A M J J A S O N D
1940
1941
ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 1.



NEW FIELDS IN 1941

1 Clay City West; Clay
2 Sailor Springs; Clay
3 Xenia; Clay
4 Boulder gas; Clinton
5 Posey; Clinton
6 Cooks Mills; Coles
7 Bone Gap; Edwards
8 Ellery; Edwards, Wayne
9 St. Paul; Fayette
10 Benton; Franklin
11 Benton North; Franklin
12 West Frankfort; Franklin
13 Inman North; Gallatin
14 Bungay; Hamilton
15 Dahlgren; Hamilton
16 Rural Hill; Hamilton
17 Walpole; Hamilton
18 Elkville; Jackson
19 Ste. Marie; Jasper
20 Ruark; Lawrence
21 St. Francisville East; Lawrence
22 South Lawrence; Lawrence
23 Carlinville North; Macoupin
24 Alma; Marion
25 Patoka East; Marion
26 Bonpas; Richland
27 Bonpas West; Richland
28 Stringtown; Richland
29 Parkersburg; Richland, Edwards
30 Eldorado; Saline
31 Lakewood; Shelby
32 Patton; Wabash
33 Geff; Wayne
34 Johnsonville; Wayne
35 Mayberry; Wayne
36 Sims; Wayne
37 Centerville East; White
38 Epworth; White
39 Grayville West; White
40 Maunie; White
41 Maunie North; White
42 Maunie South; White
43 New Harmony South; White
44 New Haven; White

ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 2.

TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
1	Warrenton-Borton, *Edgar*	1906	100	0	30,200	200	0	0	22	0	0	2	12	0
2	Westfield, *Clark, Coles*	1904	9,000	75	*x*	*x*	*x*	0	1,628	4	19	14	293	0
3			850	75	*x*	*x*	*x*	0	186	3	0	*y*	*y*	0
4			9,000	0	*x*	*x*	*x*	0	1,449	1	19	*y*	*y*	0
5			220	0	*x*	*x*	*x*	0	13	0	0	*y*	*y*	0
6	Siggins, *Cumberland, Clark*	1906	3,580	105	*x*	*x*	*x*	0	996	1	10	0	803	0
7			3,135	55	*x*	*x*	*x*	0	854	0	0	0	*y*	0
8			435	15	*x*	*x*	*x*	0	90	0	0	0	*y*	0
9			855	105	*x*	*x*	*x*	0	193	1	10	0	*y*	0
10	York, *Cumberland*	*y*	310	40	*x*	*x*	*x*	0	70	0	0	0	44	0
11	Casey, *Clark*	1906	1,925	55	*x*	*x*	*x*	0	535	2	4	0	488	0
12			190	15	*x*	*x*	*x*	0	41	0	0	0	*y*	0
13			400	0	*x*	*x*	*x*	0	82	0	0	0	*y*	0
14			1,525	15	*x*	*x*	*x*	0	322	2	4	0	*y*	0
15	Martinsville, *Clark*	1922	710	155	*x*	*x*	*x*	0	217	2	0	0	114	0
16			15	20	*x*	*x*	*x*	0	7	0	0	0	*y*	0
17			275	35	*x*	*x*	*x*	0	63	0	0	0	*y*	0
18			710	0	*x*	*x*	*x*	0	23	1	0	0	*y*	0
19			600	0	*x*	*x*	*x*	0	34	0	0	0	*y*	0
20			640	0	*x*	*x*	*x*	0	40	1	0	0	*y*	0
21			10	0	*x*	*x*	*x*	0	2	0	0	0	*y*	0
22	North Johnson, *Clark*	1907	1,320	20	*x*	*x*	*x*	0	485	0	0	0	433	0
23			1,115	0	*x*	*x*	*x*	0	296	0	0	0	*y*	0
24			160	0	*x*	*x*	*x*	0	32	0	0	0	*y*	0
25			820	5	*x*	*x*	*x*	0	177	0	0	0	*y*	0
26			215	0	*x*	*x*	*x*	0	44	0	0	0	*y*	0
27	South Johnson, *Clark*	1907	1,715	65	*x*	*x*	*x*	*x*	535	0	10	0	469	0
28			185	5	*x*	*x*	*x*	*x*	38	0	*y*	0	*y*	0
29			295	0	*x*	*x*	*x*	*x*	59	0	*y*	0	*y*	0
30			1,675	35	*x*	*x*	*x*	*x*	402	0	*y*	0	*y*	0
31			845	5	*x*	*x*	*x*	*x*	170	0	*y*	0	*y*	0
32	Bellair, *Crawford, Jasper*	1907	1,300	5	*x*	*x*	*x*	*x*	486	0	0	20	375	0
33			1,165	0	*x*	*x*	*x*	*x*	310	0	0	*y*	*y*	0
34			315	0	*x*	*x*	*x*	*x*	65	0	0	*y*	*y*	0
35			910	0	*x*	*x*	*x*	*x*	182	0	0	*y*	*y*	0
36	Clark County Division[1]		19,960	520	53,117,000	394,000	*x*	*x*	4,952	9	43	36	3,019	0
37	Main,[2] *Crawford*	1906	35,135	515	*x*	*x*	*x*	*x*	7,324	1	91	133	4,799	*y*
38			340	0	*x*	*x*	*x*	*x*	68	0	0	*y*	*y*	0
39			33,795	510	*x*	*x*	*x*	*x*	7,143	1	91	*y*	*y*	*y*
40			1,000	0	*x*	*x*	*x*	*x*	108	0	0	*y*	*y*	*y*
41			10	0	*x*	*x*	*x*	*x*	1	0	0	0	1	0
42	New Hebron, *Crawford*	1909	1,350	210	*x*	*x*	*x*	*x*	297	0	0	0	146	0
43	Chapman, *Crawford*	1914	1,045	515	*x*	*x*	*x*	*x*	193	0	1	0	60	0
44	Parker, *Crawford*	1907	1,310	30	*x*	*x*	*x*	*x*	256	0	0	0	219	0
45	Allison-Weger, *Crawford*	*y*	1,075	20	*x*	*x*	*x*	*x*	147	0	0	0	65	0
46	Flat Rock,[3] *Crawford*	*y*	1,375	545	*x*	*x*	*x*	*x*	289	0	1	0	136	0
47	Birds, *Crawford, Lawrence*	*y*	4,370	115	*x*	*x*	*x*	*x*	684	0	28	2	424	0
48	Crawford County Division[6]		45,665	1,945	147,306,000	1,398,000	*x*	*x*	9,190	1	121	135	5,849	0
49	Lawrence, *Lawrence, Crawford*	1906	24,150	1,550	*x*	*x*	*x*	*x*	4,413	8	60	13	3,205	0
50			50	0	*x*	*x*	*x*	*x*	5	3	0	0	5	0
51			5,015	35	*x*	*x*	*x*	*x*	1,233	0	*y*	*y*	*y*	0

[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Total of lines 2, 6, 10, 11, 15, 22, 27, 32.

[2] Includes Kibbie, Oblong, Robinson, and Hardinsville.

[3] Includes Swearingen gas.

[6] Total of lines 37, 42, 43, 44, 45, 46, 47.

TABLE I.—(*Continued*)

	Oil-production Methods, End of 1941		Reservoir Pressure,[4] Lb. per Sq. In.			Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
Line Number	Flowing	Artificial Lift	Initial	Avg. at End of 1941	Repressuring Operation	Gravity A.P.I. at 60°F., Weighted Average[5]	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	0	12	*x*	*x*		*x*	*x*	Unnamed	Pen	S	Por	159	215	*x*	ML	Pen	715
2	0	293	200±	*x*		34.0	*x*	See below							D	St. Peter	3,009
3	0	*y*	*x*	*x*		30.0	*x*	Shallow gas	Pen	S	Por	281	376	36	D		
4	0	*y*	*x*	*x*		33.5	*x*	Westfield	MisL	L	Cav	334	446	*x*	D		
5	0	*y*	*x*	*x*		38.2	0.18	"Trenton"	Ord	L	Por	2,265	2,568	*x*	D		
6	0	803	*x*	*x*	RP	33.0	*x*	See below							D	Dev	2,010
7	0	*y*	*x*	*x*		34.0	*x*	First Siggins	Pen	S	Por	367	465	*x*	D		
8	0	*y*	*x*	*x*		(33.6)		Second and third Siggins	Pen	S	Por	478	562	*x*	D		
9	0	*y*	*x*	*x*		(25.7)	*x*	Lower Siggins	Pen	S	Por	556	590	*x*	D		
10	0	44	*x*	*x*		(30.3)	*x*	York	Pen	S	Por	588	680	*x*	AM	Pen	960
11	0	488	*x*	*x*	RP	29.2	*x*	See below							AM	MisL	808
12	0	*y*	*x*	*x*		(31.9)	*x*	Upper gas	Pen	S	Por	263	358	*x*	AM		
13	0	*y*	*x*	*x*		(30.1)	*x*	Lower gas	Pen	S	Por	309	426	*x*	AM		
14	0	*y*	*x*	*x*		(33.6)	*x*	Casey	Pen	S	Por	444	505	*x*	AM		
15	0	114	*x*	*x*		36.8	*x*	See below							D	St. Peter	3,411
16	0	*y*	*x*	*x*		*y*	*x*	Shallow	Pen	S	Por	255	411	*x*	D		
17	0	*y*	*x*	*x*		*y*	*x*	Casey	Pen	S	Por	499	511	*x*	D		
18	0	*y*	*x*	*x*		*y*	*x*	Martinsville	MisL	L	Por	477	506	*x*	D		
19	0	*y*	*x*	*x*		(38.9)	*x*	Carper	MisL	S	Por	1,340	1,418	*x*	D		
20	0	*y*	*x*	*x*		*y*	*x*	"Niagaran"	Dev	L	Por	1,553	1,596	*x*	D		
21	0	*y*	*x*	*x*		(39.6)	*x*	"Trenton"	Ord	L	Por	2,708	2,830	*x*	D		
22	0	433	*x*	*x*		31.0	*x*	See below							AM	Mis	965
23	0	*y*	*x*	*x*		*y*	*x*	Claypool	Pen	S	Por	416	486	*x*	AM		
24	0	*y*	*x*	*x*		*y*	*x*	Shallow	Pen	S	Por	314	451	*x*	AM		
25	0	*y*	*x*	*x*		*y*	*x*	Casey	Pen	S	Por	465	508	*x*	AM		
26	0	*y*	*x*	*x*		*y*	*x*	Upper Partlow	Pen	S	Por	534	554	*x*	AM		
27	0	469	*x*	*x*		32.2	*x*	See below							AM	Dev	2,030
28	0	*y*	*x*	*x*		*y*	*x*	Claypool	Pen	S	Por	392	549	*x*	AM		
29	0	*y*	*x*	*x*		*y*	*x*	Casey	Pen	S	Por	453	518	*x*	AM		
30	0	*y*	*x*	*x*		*y*	*x*	Upper Partlow	Pen	S	Por	489	570	*x*	AM		
31	0	*y*	*x*	*x*		28.5	*x*	Lower Partlow	Pen	S	Por	598	618	*x*	AM		
32	0	375	*x*	*x*	RP	33.7	*x*	See below							AM	MisL	1,471
33	0	*y*	*x*	*x*		(32.4)	*x*	"500 Ft."	Pen	S	Por	561	726	*x*	AM		
34	0	*y*	*x*	*x*		*y*	*x*	"800 Ft."	Pen	S	Por	817	907	*x*	AM		
35	0	*y*	*x*	*x*		(37.0)	*x*	"900 Ft."	MisU	S	Por	886	920	*x*	AM		
36	0	3,019	*x*	*x*		33.0											
37	0	4,799	425±	*y*	RP	33.0	*x*	See below								St. Peter	4,654
38	0	*y*	*x*	*x*		*y*	*x*	Shallow	Pen	S	Por	508	822	*x*	ML		
39	0	*y*	*x*	*x*		32.8	*x*	Robinson	Pen	S	Por	900	960	25±	ML		
40	0	*y*	*x*	*x*		*y*	*x*	Oblong	Mis	S, L	Por	1,337	1,416	*x*	A, ML		
41	0	1	*x*	*x*		*y*	*x*	Devonian	Dev	L	Por	2,794	2,805	11	ML		
42	0	146	*x*	*x*	RP	30.1	*x*	Robinson	Pen	S	Por	940	975	*x*	ML	Mis	2,056
43	0	60	*x*	*x*		*y*	*x*	Robinson	Pen	S	Por	995	1,015	*x*	ML	Mis	2,279
44	0	219	*x*	*x*		29.5	*x*	Robinson	Pen	S	Por	1,000	1,025	*x*	ML	Pen	1,127
45	0	65	*x*	*x*		22.5	*x*	Robinson	Pen	S	Por	912	930	*x*	ML	Pen	1,041
46	0	136	*x*	*x*	RP	31.8		Robinson (Flat Rock)	Pen	S	Por	935	945	*x*	ML	Dev	3,110
47	0	424	*x*	*x*	RP	31.8	*x*	Robinson	Pen	S	Por	930	950	*x*	ML	MisL	1,731
48	0	5,849	425±	*x*		32.3	*x*									St. Peter	4,654
49	0	3,205	650±	*x*	RP	32.9	*x*	See below							A	St. Peter	5,190
50	0	5	*x*	*x*		*y*	*x*	Pennsylvanian	Pen	S	Por	290	320	*x*	A		
51	0	*y*	*x*	*x*		*y*	*x*	Bridgeport	Pen	S	Por	800	1,000	40	A		

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[4] Pressures in southeastern Illinois oil fields are estimated bottom-hole pressures reported in previous Survey publications.

[5] All gravities given prior to 1936 (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples (see Illinois State Geol. Survey *Bull.* 54, Table 3). The values have been converted from Baumé to A.P.I. gravities.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
52			2,240	0	*x*	*x*	*x*	*x*	476	1	*y*	*y*	*y*	0
53			345	1,095	*x*	*x*	*x*	*x*	243	0	*y*	*y*	*y*	0
54			15,960	220	*x*	*x*	*x*	*x*	3,017	0	*y*	*y*	*y*	0
55			4,020	200	*x*	*x*	*x*	*x*	691	3	*y*	*y*	*y*	0
56			6,950	0	*x*	*x*	*x*	*x*	959	1	*y*	*y*	*y*	0
57	St. Francisville, *Lawrence*...		420	0	*x*	*x*	*x*	*x*	55	0	1	0	30	0
58	Lawrence County Division[7]..		24,570	1,550	227,790,000	1,826,000	*x*	*x*	4,468	8	61	13	3,235	0
59	Allendale, *Wabash*	1912	1,680	0	5,106,000	257,000	*x*	*x*	473	46	1	0	252	0
60			*y*	0	*x*	*x*	*x*	*x*	430	3	1	0	209	0
61			*y*	0	*x*	*x*	*x*	*x*	3	3	0	0	3	0
62			*y*	0	*x*	*x*	*x*	*x*	3	3	0	0	3	0
63			*y*	0	*x*	*x*	*x*	*x*	6	6	0	0	6	0
64			*y*	0	*x*	*x*	*x*	*x*	24	24	0	0	24	0
65			*y*	0	*x*	*x*	*x*	*x*	7	7	0	0	7	0
66	Total Southeastern Fields[8]..		91,855	3,970	433,349,200	3,875,200	*x*	*x*	19,105	61	226	186	12,367	0
67	Ayers gas, *Bond*............	1922	0	325	0	0	207.8	13.4	19	0	0	0	0	7
68	Greenville gas, *Bond*........	1910[9]	0	160	0	0	990.0	0	4	0	0	0	0	0
69	Bartelso, *Clinton*...........	1936	580	0	1,017,000	278,000	0	0	72	8	2	0	70	0
70			320	0	677,000	149,000	0	0	47	7	2	0	45	0
71			230	0	340,000	129,000	0	0	25	1	0	0	25	0
72	Carlyle, *Clinton*............	1911	915	0	3,428,000	26,000	0	0	165	0	0	40	103	0
73	Frogtown, *Clinton*..........	1918[10]	300	0	*x*	0	0	0	12	0	0	0	0	0
74	Ava-Campbell Hill, *Jackson*.	1917[11]	70	370	*x*	0	*x*	0	35	0	0	0	0	0
75	Colmar-Plymouth, *McDonough, Hancock*	1914	2,450	0	2,787,000	114,000	0	0	485	3	0	71	218	0
76	Carlinville, *Macoupin*.......	1909[12]	30	50	*x*	0	*x*	0	8	0	0	0	0	0
77	Gillespie-Benld gas, *Macoupin*	1923[13]	0	80	0	0	135.8	0	4	0	0	0	0	0
78	Gillespie-Wyen, *Macoupin*..	1915	40	0	*x*	0	0	0	22	0	0	12	0	0
79	Spanish Needle Creek gas, *Macoupin*	1915[14]	0	80	0	0	14.4	0	7	0	0	0	0	0
80	Staunton gas, *Macoupin*....	1916[15]	0	400	0	0	1,050.0	0	18	0	0	0	0	0
81	Collinsville, *Madison*.......	1909[16]	40	0	850	0	0	0	6	0	0	0	0	0
82	Brown-Langewisch Kuester-Junction City, *Marion*	1910	175	0	*x*	*x*	0	0	10	0	0	0	9	0
83			60	0	*x*	*x*	0	0	6	0	0	0	5	0
84			115	0	*x*	*x*	0	0	4	0	0	0	4	0
85	Sandoval, *Marion*..........	1909	770	0	4,631,000	450,000	0	0	150	1	22	0	28	0
86			770	0	2,690,000	10,000	0	0	123	0	13	0	10	0
87			380	0	1,941,000	440,000	0	0	27	1	9	0	18	0
88	Wamac, *Marion, Clinton, Washington*	1921	250	0	439,000	17,000	0	0	104	0	6	0	30	0
89	Litchfield, *Montgomery*......	1879[17]	100	0	22,000	0	0	0	18	0	0	0	0	0
90	Waterloo, *Monroe*..........	1920[18]	230	0	214,000	17,000	0	0	41	3	0	0	15	0
91	Jacksonville gas, *Morgan*....	1910[19]	30	1,290	2,100	0	*x*	0	53	0	0	0	0	0
92	Pittsfield (Pike County) gas, *Pike*	1886[20]	0	8,960	0	0	*x*	0	68	0	0	0	0	0
93	Sparta, *Randolph*..........	1888[21]	65	100	*x*	0	*x*	0	20	0	0	0	0	0
94	Dupo, *St. Clair*............	1928	670	0	1,579,000	304,000	0	0	290	27	0	0	91	0
95	Total for fields discovered prior to Jan. 1, 1937[22]		98,600	15,830	447,533,000	5,145,000	2,388.0	13.4	20,716	106	256	309	12,931	7

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[7] Total of lines 49 and 57.
[8] Total of lines 1, 36, 48, 58, 59.
[9] Abandoned 1923.
[10] Abandoned 1933.
[11] Abandoned 1934.
[12] Abandoned 1925.
[13] Abandoned 1935.
[14] Abandoned 1934.
[15] Abandoned 1919.
[16] Abandoned 1921.
[17] Abandoned 1904.
[18] Abandoned 1930, revived 1939.
[19] Abandoned 1937.
[20] Gas not used until 1905; abandoned 1930.
[21] Abandoned 1900.
[22] Total of lines 66 to 94 inclusive.

TABLE I.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
52	0	*y*	*x*	*x*		*y*	*x*	Buchanan	Pen	S	Por	1,250	1,265	15	A		
53	0	*y*	*x*	*x*		*y*	*x*	"Gas"	MisU	S	Por	1,330	1,345	15	A		
54	0	*y*	600±	*x*		*y*	*x*	Kirkwood	MisU	S	Por	1,400	1,430	30	A		
55	0	*y*	650±	*x*		*y*	*x*	Tracey	MisU	S	Por	1,560	1,580	20	A		
56	0	*y*	*x*	*x*		*y*	*x*	McClosky	MisL	L	Por	1,700	1,710	10	A		
57	0	30	600	*x*		37.3	*x*	Bethel	MisU	S	Por	1,843	1,865	22	ML	Mis	1,900
58	0	3,235	*x*	*x*												St. Peter	5,190
59	0	252			RP										AM	MisL	2,367
60	0	209	*x*	*x*		35.1	*x*	Biehl	Pen	S	Por	1,425	1,460	20			
61	0	3	*x*	*x*		*y*	*x*	Waltersburg	MisU	S	Por	1,540	1,560	15			
62	0	3	*x*	*x*		*y*	*x*	Tar Springs	MisU	S	Por	1,620	1,640	20			
63	0	6	*x*	*x*		*y*	*x*	Cypress	MisU	S	Por	1,920	1,930	10			
64	0	24	*x*	*x*		*y*	*x*	Bethel	MisU	S	Por	2,010	2,020	9			
65	0	7	900	*x*		*y*	*x*	McClosky	MisL	L	Por	2,280	2,290	8			
66	0	12,367															
67			335	*y*				Lindley (2d)	MisU	S	Por	940	945	5	A	Dev	2,181
68			*x*					Lindley (1st., 2d)	MisU	S	Por	927	993	*x*	A	Dev	2,290
69	0	70													D	St. Peter	4,213
70	0	45	*x*	*x*		36.2	0.20	Carlyle	MisU	S	Por	984	1,008	24	D		
71	0	25	*x*	*x*		41.5	0.27	Devonian	Dev	L	Por	2,429	2,447	9	D		
72	0	103	*x*	*x*		35.2	0.26	Carlyle	MisU	S	Por	1,035	1,055	20	A	St. Peter	4,120
73	0	0	*x*			31.9	*x*	Carlyle	MisU	S	Por	950	957	7	D	Cypress	962
74	0	0	*x*			*x*	*x*	Cypress	MisU	S	Por	780	798	18	A	Dev	2,530
75	0	218	*x*	*x*	RP	37.6	0.38	Hoing	Dev	S	Por	447	468	21	A	"Trenton"	805
76	0	0	135			27.7	*x*	Unnamed	Pen	S	Por	380	398	*x*	A	Pen	410
77	0	0	155					Unnamed	Pen	S	Por	542	555	*x*	A	Pen	575
78	0	0	*x*	*x*		30.0	*x*	Unnamed	Pen	S	Por	650	670	*x*	T	"Trenton"	2,560
79	0	0	*x*					Unnamed	Pen	S	Por	305	405	*x*	D	Pen	495
80	0	0	145					Unnamed	Pen	S	Por	461	491	*x*	A	"Trenton"	2,371
81	0	0	*x*			*x*	*x*	Devonian-Silurian	Dev-Sil	L	Por	1,305	1,400	20	ML	Sil	1,500
82	0	9															
83	0	5	*x*	*x*		32.0	*x*	Dykstra, Wilson	Pen	S	Por	610	630	20	D	MisL	2,001
84	0	4	*x*	*x*		32.0	*x*	Cypress	MisU	S	Por	1,658	1,673	15	D	Dev	3,344
85	0	28													D	St. Peter	5,023
86	0	10	*x*	*x*		34.5	*x*	Benoist	MisU	S	Por	1,540	1,560	20±	D		
87	0	18	*x*	*x*		38.0	0.38	Devonian	Dev	L	Por	2,924	2,969	9	D		
88	0	30	*x*	*x*		30.2	*x*	Petro	Pen	S	Por	720	760	20	D	MisL	1,760
89	0	0	*x*			23.0	0.42	Unnamed	Pen	S	Por	664	674	*x*	D	Pen	681
90	0	15	*x*	*x*		30.2	0.79	"Trenton"	Ord	L	Por	410	460	50	A	"Trenton"	845
91	0	0	*x*			*x*	*x*	Gas	Pen, MisL	S, SL	Por	330	335	5	ML	"Trenton"	1,390
92	0	0	*x*					"Niagaran"	Sil	L	Por	265	275	10	A	St. Peter	893
93	0	0	*x*			*x*	*x*	Cypress	MisU	S	Por	850	857	7	D	MisU	985
94	0	91	*x*	*x*		32.7	0.70	"Trenton"	Ord	L	Por	561	601	50	A	"Trenton"	819
95	0	12,931															

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
96	Sorento, *Bond*	1938	30	0	4,000	0	0	0	3	0	0	1	0	0
97	Woburn, *Bond*	1940	200	0	257,000	164,000	0	0	27	3	0	0	27	0
98	Clay City West, *Clay*	1941	40	0	*x*	*x*	0	0	2	2	0	0	2	0
99	Flora, *Clay*	1938	250	0	386,000	78,000	0	0	21	2	2	0	18	0
100			10	0	*x*	*x*	0	0	1	1	0	0	1	0
101			*y*	0	*x*	*x*	0	0	3	1	0	0	3	0
102			10	0	*x*	*x*	0	0	1	0	0	0	1	0
103			*y*	0	*x*	*x*	0	0	16	0	2	0	13	0
104	Iola, *Clay*	1939[23]	70	0	11,000	3,000	0	0	5	3	0	0	3	0
105	Xenia, *Clay*	1941	10	0	1,500	1,500	0	0	1	1	0	0	1	0
106	Sailor Springs, *Clay*	1941	230	0	165,000	165,000	0	0	25	25	0	0	25	0
107			*x*	0	*x*	*x*	0	0	20	20	0	0	20	0
108			*x*	0	*x*	*x*	0	0	4	4	0	0	4	0
109			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
110	Clay City Consolidated, *Clay, Wayne*	1937	12,950	0	24,891,000	4,969,000	0	0	700	118	11	4	676	
111			*x*	0	*x*	*x*	0	0	23	20	0	0	23	0
112			*x*	0	*x*	*x*	0	0	1	0	0	0	1	0
113			*x*	0	*x*	*x*	0	0	9	7	0	0	9	0
114			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
115			*x*	0	*x*	*x*	0	0	656	83	11	4	632	0
116									8	5	0	0	8	0
117	Boulder gas, *Clinton*	1941	0	10	0	0	0	0	1	1	0	1	0	0
118	Hoffman, *Clinton*	1939	300	0	266,000	150,000	0	0	44	3	0	0	44	0
119			*x*	0	*x*	*x*	0	0	10	2	0	0	10	0
120			*x*	0	*x*	*x*	0	0	34	1	0	0	34	0
121	Posey, *Clinton*	1941	20	0	2,000	2,000	0	0	2	2	0	0	2	0
122	West Centralia, *Clinton*	1940	70	0	*x*	*x*	0	0	6	5	0	0	6	0
123	Centralia, *Clinton*	1937	2,850	0	20,098,000	3,578,000	0	0	906	8	82	4	797	0
124			*x*	0	*x*	*x*	0	0	23	1	0	0	23	0
125			*x*	0	*x*	*x*	0	0	562	5	9	2	529	0
126			*x*	0	10,730,000	1,630,000	0	0	319	2	73	1	244	0
127			*x*	0	20,000	7,000	0	0	2	0	0	1	1	0
128	Cooks Mills, *Coles*	1941	10	0	1,000	1,000	0	0	1	1	0	0	1	0
129	Mattoon, *Coles*	1939[24]	20	0	17,000	8,000	0	0	2	0	0	0	1	0
130			10	0	*x*	*x*	0	0	1	0	0	0	0	0
131			10	0	17,000	8,000	0	0	1	0	0	0	1	0
132	Albion, *Edwards*	1940	820	0	1,841,000	886,000	0	0	79	20	1	0	78	0
133			*x*	0	*x*	*x*	0	0	3	0	0	0	3	0
134			*x*	0	*x*	*x*	0	0	10	0	0	0	10	0
135			*x*	0	*x*	*x*	0	0						
136			*x*	0	*x*	*x*	0	0						
137			*x*	0	*x*	*x*	0	0	61	15	1	0	60	0
138									5	5	0	0	5	0
139	Bone Gap, *Edwards*	1941	20	0	66,000	66,000	0	0	4	4	0	0	4	0
140	Cowling, *Edwards*	1939	100	0	245,000	169,000	0	0	13	0	1	0	11	0
141	Ellery, *Edwards, Wayne*	1941	20	0	13,000	13,000	0	0	2	2	0	0	2	0
142	Grayville, *Edwards, White*	1939	80	0	124,000	29,000	0	0	8	0	1	0	4	0
143	Mason, *Effingham*	1940	120	0	154,000	145,000	0	0	16	15	0	0	16	0
144			80	0	*x*	*x*	0	0	8	8	0	0	8	0
145			80	0	*x*	*x*	0	0	8	7	0	0	8	0
146	Louden, *Fayette, Effingham*	1937	19,750	0	69,719,000	22,918,000	0	0	1,934	181	9	2	1,912	0
147			19,750	0	*x*	*x*	0	0	939	84	0	1	927	0
148			11,000	0	*x*	*x*	0	0	323	11	1	1	321	0
149			7,000	0	*x*	*x*	0	0	425	4	7	0	418	0
150			2,400	0	1,030,000	1,030,000	0	0	59	59	0	0	59	0
151									188	23	1	0	187	0

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[23] Abandoned 1940; revived 1941.

[24] Abandoned 1939; revived 1940.

TABLE I—(*Continued*)

Line Number	Oil-production Methods, End of 1941, Number of Wells: Flowing	Artificial Lift	Reservoir Pressure, Lb. per Sq. In.: Initial	Avg. at End of 1941	Repressuring Operation[d]	Character of Oil: Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Producing Formation: Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.: Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Deepest Zone Tested to End of 1941: Name	Depth of Hole, Ft.
96	0	0	*x*	*x*		*x*	*x*	Devonian	Dev	L	Por	1,830	1,893	5	D	Dev	1,893
97	0	27	*x*	*x*		36.4	0.20	Bethel	MisU	S	Por	1,008	1,024	11	A	Dev	2,454
98	0	2	*x*	*x*		*y*	*y*	McClosky	MisL	L	Por	3,050	3,080	15	A	MisL	3,080
99	0	18													D	MisL	3,100
100	0	1	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	2,320	2,332	12			
101	0	3	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	2,595	2,614	5			
102	0	1	*x*	*x*		37.4	*x*	Bethel	MisU	S	Por	2,788	2,800	12			
103	0	13	*x*	*x*		37.2	0.24	McClosky	MisL	L	Por	2,965	2,978	6			
104	0	3	*x*	*x*		35.4	0.25	Aux Vases	MisU	S	Por	2,335	2,351	11	D	MisU	2,383
105	0	1	*x*	*x*		35.2	*x*	Aux Vases	MisU	S	Por	2,785	2,806	12	D	MisU	2,806
106	0	25													D	MisL	3,047
107	0	20	*x*	*x*		39.5	0.29	Tar Springs	MisU	S	Por	2,340	2,360	15			
108	0	4	*x*	*x*		38.5	*x*	Cypress	MisU	S	Por	2,590	2,610	10			
109	0	1	*x*	*x*		36.4	*x*	McClosky	MisL	L	Por	3,009	3,047	5			
110	4	672			PM										A	Dev	4,840
111	0	23	*x*	*x*		37.9	*x*	Cypress	MisU	S	Por	2,670	2,680	10			
112	0	1	*x*	*x*		38.0	*x*	Bethel	MisU	S	Por	2,880	2,885	5			
113	0	9	*x*	*x*		38.0	*x*	Aux Vases	MisU	S	Por	2,910	2,935	15			
114	0	3	*x*	*x*		38.0	*x*	Rosiclare	MisL	S	Por	2,970	2,974	4			
115	4	628	*x*	*x*		38.5	*x*	McClosky	MisL	L	Por	2,980	2,990	10			
116	0	8						[33]									
117	0	0	*x*	*x*				Devonian	Dev	L	Por	2,618	2,668	50	D	Dev	2,668
118	0	44													D	Dev	2,914
119	0	10	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	1,185	1,201	9			
120	0	34	*x*	*x*		32.2	0.21	Bethel	MisU	S	Por	1,319	1,326	7			
121	0	2	*x*	*x*		36.1	0.17	Cypress	MisU	S	Por	1,105	1,110	5	D	MisU	1,110
122	0	6	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	1,408	1,415	7	D	MisU	1,415
123	0	797			PM										A	"Trenton"	4,068
124	0	23	*x*	100		36.4	*x*	Cypress	MisU	S	Por	1,200	1,215	15			
125	0	529	*x*	10		37.4	*x*	Bethel	MisU	S	Por	1,355	1,375	20			
126	0	244	*x*	275		37.4	0.38	Devonian	Dev	L	Por	2,860	2,874	14			
127	0	1	*x*	*x*		43.2	0.28	"Trenton"	Ord	L	Por	4,020	4,120	40			
128	0	1	*x*	*x*		37.0	*x*	Aux Vases	MisU	S	Por	1,824	1,834	10	A	MisU	1,842
129	0	1													A	St. Peter	4,908
130	0	0	*x*	*x*		44.1	0.16	Cypress	MisU	S	Por	1,835	1,919	25			
131	0	1	*x*	*x*		36.6	0.29	McClosky	MisL	L	Por	2,000	2,027	12			
132	0	78													A	Dev	5,185
133	0	3	*x*	*x*		34.0	*x*	Bridgeport	Pen	S	Por	1,571	1,622	10			
134	0	10	*x*	*x*		34.0	*x*	Waltersburg	MisU	S	Por	2,365	2,375	10			
135			*x*	*x*		38.0	*x*	Bethel[34]	MisU	S	Por	2,935	2,949	14			
136			*x*	*x*		39.0	*x*	Aux Vases[34]	MisU	S	Por	3,040	3,056	16			
137	0	60	*x*	200		40.0	0.18	McClosky	MisL	L	Por	3,108	3,119	11			
138	0	5						[33]									
139	0	4	*x*	*x*		38.5	*x*	McClosky	MisL	L	Por	3,266	3,325	8	D	MisL	3,325
140	0	11	*x*	*x*		36.6	0.23	Cypress	MisU	S	Por	2,620	2,640	12	D	MisL	3,175
141	0	2	*x*	*x*		39.1	*x*	McClosky	MisL	L	Por	3,341	3,343	12	D	MisL	3,343
142	0	4	*x*	*x*		35.8	0.31	McClosky	MisL	L	Por	3,093	3,188	6	A	MisL	3,269
143	0	16													A	MisL	2,500
144	0	8	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,305	2,316	11			
145	0	8	*x*	*x*		38.1	*x*	McClosky	MisL	L	Por	2,490	2,497	7			
146	290	1,622			PM										A	St. Peter	4,679
147	65	862	*x*	338		36.6	0.25	Cypress	MisU	S	Por	1,493	1,515	22			
148	5	316	*x*	401		37.8	0.24	Paint Creek	MisU	S	Por	1,530	1,545	15			
149	5	413	*x*	382		38.5	0.20	Bethel	MisU	S	Por	1,550	1,566	16			
150	44	15	*x*	1,331		29.0	0.40	Devonian	Dev	L	Por	3,000	3,025	15			
151	171	16						[33]									

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[33] Wells producing from more than one sand, see Table 2.

[34] Producing in combination wells.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[e]	Producing Gas[e]
152	St. James, *Fayette*	1938	1,880	0	4,178,000	1,965,000	0	0	188	11	0	2	180	0
153	St. Paul, *Fayette*	1941	20	0	2,000	2,000	0	0	2	2	0	0	2	0
154	Benton, *Franklin*	1941	1,865	0	6,990,000	6,990,000	0	0	222	222	0	0	222	0
155	Benton North, *Franklin*	1941	60	0	33,000	33,000	0	0	6	6	0	0	6	0
156			20	0	*x*	*x*	0	0	2	2	0	0	2	0
157			20	0	*x*	*x*	0	0	2	2	0	0	2	0
158			20	0	*x*	*x*	0	0	2	2	0	0	2	0
159	Thompsonville, *Franklin*	1940	220	0	188,000	117,000	0	0	19	3	0	0	19	0
160	West Frankfort, *Franklin*	1941	10	0	*x*	*x*	0	0	1	1	0	0	1	0
161	Whittington, *Franklin*	1939	10	0	16,000	5,000	0	0	1	0	0	0	1	0
162	Inman, *Gallatin*	1940	40	0	156,000	154,000	0	0	7	7	0	0	7	0
163			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
164			*x*	0	*x*	*x*	0	0	4	4	0	0	4	0
165			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
166			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
167	Inman East, *Gallatin*	1940	290	0	312,000	310,000	0	0	36	36	0	1	35	0
168			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
169			*x*	0	*x*	*x*	0	0	24	24	0	1	23	0
170			*x*	0	*x*	*x*	0	0	6	6	0	0	6	0
171			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
172	Inman North, *Gallatin*	1941	20	0	5,000	5,000	0	0	2	2	0	0	2	0
173	Junction, *Gallatin*	1939	150	0	168,000	44,000	0	0	14	0	0	0	14	0
174	Omaha, *Gallatin*	1940	260	0	370,000	364,000	0	0	20	19	0	1	19	0
175			*x*	0	*x*	*x*	0	0	17	16	0	1	16	0
176			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
177	Belle Prairie, *Hamilton*	1940	20	0	35,000	32,000	0	0	2	1	0	0	2	0
178	Bungay, *Hamilton*	1941	10	0	3,000	3,000	0	0	1	1	0	0	1	0
179	Dahlgren, *Hamilton*	1941	540	0	681,000	681,000	0	0	42	42	0	0	42	0
180	Dale, *Hamilton*	1940	1,230	0	2,884,000	2,555,000	0	0	136	112	1	0	135	0
181			*x*	0	*x*	*x*	0	0	27	5	0	0	27	0
182			*x*	0	*x*	*x*	0	0	8	8	0	0	8	0
183			*x*	0	*x*	*x*	0	0	72	72	0	0	72	0
184			*x*	0	*x*	*x*	0	0	20	18	1	0	19	0
185									9	9	0	0	9	0
186	Hoodville, *Hamilton*	1940	1,310	0	4,069,000	3,725,000	0	0	155	103	0	1	154	0
187			*x*	0	*x*	*x*	0	0	76	26		1	75	0
188			*x*	0	*x*	*x*	0	0	42	42	0	0	42	0
189			*x*	0	*x*	*x*	0	0	4	2	0	0	4	0
190									33	33	0	0	33	0
191	Rural Hill, *Hamilton*	1941	900	0	1,615,000	1,615,000	0	0	95	95	0	0	95	0
192			*x*	0	*x*	*x*	0	0	39	39	0	0	39	0
193			*x*	0	*x*	*x*	0	0	5	5	0	0	5	0
194			*x*	0	*x*	*x*	0	0	19	19	0	0	19	
195									32	32	0	0	32	0
196	Walpole, *Hamilton*	1941	270	0	208,000	208,000	0	0	18	18	0	0	18	0
197	Elkville, *Jackson*	1941	10	0	500	500	0	0	1	1	0	0	1	0
198	Hidalgo, *Jasper*	1940	20	0	7,000	2,000	0	0	2	0	1	1	0	0
199	North Boos, *Jasper*	1940	540	0	995,000	805,000	0	0	46	36	0	0	46	0
200	Ste. Marie, *Jasper*	1941	40	0	16,000	16,000	0	0	3	3	0	0	3	0
201	Cravat, *Jefferson*	1939	100	0	125,000	48,000	0	0	11	0	0	0	11	0
202	Dix, *Jefferson*	1938	1,460	0	2,360,000	778,000	0	0	76	11	0	0	76	0
203	Elk Prairie, *Jefferson*	1938[25]	10	0	700	0	0	0	1	0	0	0	0	0
204	Ina, *Jefferson*	1938[26]	10	0	15,000	1,000	0	0	1	0	1	0	0	0
205	Marcoe, *Jefferson*	1938[27]	20	0	12,500	500	0	0	2	0	1	0	0	0
206	Roaches, *Jefferson*	1938	120	0	334,000	89,000	0	0	10	0	0	0	10	0
207	Woodlawn, *Jefferson*	1940	1,120	0	2,533,000	2,532,000	0	0	137	136	0	2	135	0
208	Ruark, *Lawrence*	1941	10	0	*x*	*x*	0	0	1	1	0	0	1	0

[25] Abandoned 1940.

[26] Abandoned 1941.

[27] Abandoned 1941.

TABLE I.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
152	0	180	x	x		34.4	0.31	Cypress	MisU	S	Por	1,581	1,600	16	A	Dev	3,375
153	0	2	x	x		34.0	x	Bethel	MisU	S	Por	1,885	1,906	6	D	MisU	1,906
154	0	222	x	x		40.6	0.11	Tar Springs	MisU	S	Por	2,100	2,150	34	A	MisL	3,203
155	0	6													D	MisL	2,800
156	0	2	x	x		x	x	Bethel	MisU	S	Por	2,606	2,623	10			
157	0	2	x	x		x	x	Aux Vases	MisU	S	Por	2,689	2,700	10			
158	0	2	x	x		x	x	McClosky	MisL	L	Por	2,783	2,792	5			
159	0	19	x	x		37.8	0.16	McClosky	MisL	L	Por	3,121	3,136	10	A	MisL	3,136
160	0	1	x	x		x	x	Tar Springs	MisU	S	Por	2,054	2,080	14	D	MisL	2,989
161	0	1	x	x		37.6	0.24	McClosky, St. Louis	MisL	L	Por	2,869	3,068	9	D	MisL	3,068
162	0	7													D	MisL	2,941
163	0	1	x	x		36.0	x	Palestine	MisU	S	Por	1,832	1,842	10			
164	0	4	x	x		36.9	x	Tar Springs	MisU	S	Por	2,073	2,090	8			
165	0	1	x	x		x	x	Cypress	MisU	S	Por	2,400	2,441	5			
166	0	1	x	x		x	x	Aux Vases	MisU	S	Por	2,743	2,778	13			
167	0	35													A	MisL	2,869
168	0	3	x	x		24.4	0.31	Pennsylvanian	Pen	S	Por	780	792	12			
169	0	23	x	x		33.3	x	Tar Springs	MisU	S	Por	2,082	2,097	15			
170	0	6	x	x		x	x	Cypress	MisU	S	Por	2,430	2,440	10			
171	0	3	x	x		x	x	McClosky	MisL	L	Por	2,804	2,910	10			
172	0	2	x	x		x	x	McClosky	MisL	L	Por	2,850	3,020	15	D	MisL	3,020
173	0	14	x	x		37.2	0.22	Waltersburg	MisU	S	Por	1,763	1,804	15	D	MisL	2,711
174	0	19													D	MisL	3,578
175	0	16	x	425		25.9	0.23	Palestine	MisU	S	Por	1,690	1,710	20			
176	0	0	x	425		27.0	x	Tar Springs	MisU	S	Por	1,880	1,890	10			
177	0	2	x	x		37.0	0.12	McClosky	MisL	L	Por	3,467	3,578	6	D	MisL	3,578
178	0	1	x	x		x	x	Aux Vases	MisU	S	Por	3,275	3,290	15	D	MisL	3,513
179	0	42	x	x		38.7	0.18	McClosky	MisL	L	Por	3,337	3,359	10	A	MisL	3,359
180	10	125													D	MisL	3,257
181	0	27	x	x		37.6	0.25	Cypress	MisU	S	Por	2,678	2,708	18			
182	0	8	x	x		39.0	x	Bethel	MisU	S	Por	2,890	2,910	20			
183	6	66	x	x		38.5	x	Aux Vases	MisU	S	Por	2,970	3,000	30			
184	0	19	x	x		39.0	x	McClosky	MisL	L	Por	3,143	3,185	10			
185	4	5	x	x				33									
186	2	152													D	MisL	3,224
187	0	75	x	x		39.0	0.19	Bethel	MisU	S	Por	2,952	2,975	20			
188	1	41	x	x		39.0	0.39	Aux Vases	MisU	S	Por	3,050	3,065	15			
189	0	4	x	x		39.0	x	McClosky	MisL	L	Por	3,146	3,224	10			
190	1	32						33									
191	21	74													A	MisL	3,320
192	0	39	x	x		38.0	0.15	Aux Vases	MisU	S	Por	3,135	3,160	25			
193	0	5	x	x		x	x	Levias	MisL	L	Por	3,200	3,230	30			
194	9	10	x	x		38.6	0.19	McClosky	MisL	L	Por	3,260	3,320	22			
195	12	20						33									
196	0	18	x	x		39.0	x	Aux Vases	MisU	S	Por	3,050	3,085	35	A	MisL	3,289
197	0	1	x	x		x	x	Bethel	MisU	S	Por	2,000	2,011	11	D	MisL	2,387
198	0	0	x	x		38.8	x	McClosky	MisL	L	Por	2,560	2,607	8	N	Dev	4,139
199	0	46	x	x		38.6	0.20	McClosky	MisL	L	Por	2,791	2,834	8	A	MisL	2,834
200	0	3	x	x		41.0	x	McClosky	MisL	L	Por	2,823	2,833	8	A	MisL	2,833
201	0	11	x	x		35.4	0.23	Bethel	MisU	S	Por	2,066	2,077	11	D	MisL	2,356
202	0	76	x	290	PM	39.0	0.18	Bethel	MisU	S	Por	1,948	1,961	13	A	Devonian	3,650
203	0	0	x	x		x	x	McClosky	MisL	L	Por	2,718	2,751	7	D	MisL	2,958
204	0	0	x	x		36.4	0.20	St. Louis	MisL	L	Por	3,002	3,007	5	D	MisL	3,064
205	0	0	x	x		23.2	0.54	McClosky	MisL	L	Por	2,746	2,765	11	D	MisL	3,066
206	0	10	x	x		37.0	0.22	McClosky, Rosiclare	MisL	L, S	Por	2,187	2,257	22	D	MisL	2,285
207	0	135	x	250		37.8	0.16	Bethel	MisU	S	Por	1,960	1,984	24	A	MisL	2,304
208	0	1	x	x		32.0	x	Buchanan	Pen	S	Por	1,514	1,531	14	D	MisL	2,320

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas^b	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c
209	Russellville gas, *Lawrence*...	1937	0	1,620	0	0	2,818.5	863.0	49	8	1	0	0	48
210			0	1,600	0	0	*x*	*x*	8	4	0	0	0	8
211			0	260	0	0	*x*	*x*	41	4	1	0	0	40
212	St. Francisville East, *Lawrence*	1941	30	0	*x*	*x*	0	0	3	3	0	0	3	0
213	South Lawrence, *Lawrence*..	1941	60	0	*x*	*x*	0	0	7	7	0	0	7	0
214	Carlinville North, *Macoupin*	1941	30	0	*x*	*x*	0	0	3	3	0	0	3	0
215	Alma, *Marion*............	1941	20	0	8,000	8,000	0	0	2	2	0	0	2	0
216	Patoka, *Marion*...........	1937	900	0	2,496,000	418,000	0	0	130	13	4	0	113	0
217			885	0	*x*	*x*	0	0	127	12	4	0	110	0
218			15	0	*x*	*x*	0	0	3	1	0	0	3	0
219	Patoka East, *Marion*.......	1941	430	0	663,000	663,000	0	0	56	56	0	0	56	0
220			0	0	*x*	*x*	0	0	51	51	0	0	51	0
221			0	0	*x*	*x*	0	0	5	5	0	0	5	0
222	Salem, *Marion*............	1938	9,070	0	152,266,000	29,510,000	0	0	2,416	11	13	27	2,358	0
223			9,070	0	*x*	*x*	0	0	459	4	0	16	439	0
224			*x*	0	*x*	*x*	0	0	152	6	2	1	149	0
225			*x*	0	*x*	*x*	0	0	550	0	9	3	523	0
226			*x*	0	*x*	*x*	0	0	8	0	0	0	8	0
227			5,000	0	31,530,000	3,930,000	0	0	541	1	2	2	439	0
228			1,000	0	918,000	918,000	0	0					99	0
229									706	0	0	5	701	0
230	Tonti, *Marion*............	1939	380	0	4,730,000	1,261,000	0	0	55	6	0	1	54	0
231			*x*	0	*x*	*x*	0	0	5	1	0	0	5	0
232			*x*	0	*x*	*x*	0	0	15	5	0	0	15	0
233			*x*	0	*x*	*x*	0	0	29	0	0	1	28	0
234			*x*	0	1,250,000	572,000	0	0	6	0	0	0	6	0
235	Fairman, *Marion, Clinton*...	1939	490	0	536,000	305,000	0	0	25	9	0	0	24	0
236	Raymond, *Montgomery*.....	1940	30	0	2,400	1,900	0	0	3	1	0	0	2	0
237	Waggoner, *Montgomery*.....	1940	40	0	3,000	2,000	0	0	4	0	0	0	4	0
238	Bonpas, *Richland*..........	1941	20	0	19,000	19,000	0	0	1	1	0	0	1	0
239	Bonpas West, *Richland*.....	1941	80	0	47,000	47,000	0	0	7	7	0	0	6	0
240			10	0	*x*	*x*	0	0	1	1	0	0	1	0
241			10	0	*x*	*x*	0	0	1	1	0	0	1	0
242			60	0	*x*	*x*	0	0	5	5	0	1	4	0
243	Dundas Consolidated, *Richland, Jasper*	1939	4,630	0	7,089,000	4,377,000	0	0	240	115	3	0	237	0
244			10	0	*x*	*x*	0	0	1	1	0	0	1	0
245			10	0	*x*	*x*	0	0	1	1	0	0	1	0
246			4,630	0	*x*	*x*	0	0	236	112	3	0	233	0
247			20	0	*x*	*x*	0	0	2	2	0	0	2	0
248	Noble, *Richland*...........	1937	3,740	0	10,147,000	576,000	0	0	264	18	5	7	231	0
249			*x*	0	*x*	*x*	0	0	89	17	1	0	88	0
250			*x*	0	*x*	*x*	0	0	175	1	4	7	143	0
251	Olney, *Richland*...........	1937	520	0	1,095,000	133,000	0	0	37	0	1	0	34	0
252	Schnell, *Richland*..........	1938	40	0	163,000	13,000	0	0	4	0	0	0	4	0
253	Stringtown, *Richland*.......	1941	20	0	15,000	15,000	0	0	3	3	0	0	3	0
254	Parkersburg, *Richland, Edwards*	1941	330	0	743,000	743,000	0	0	24	24	0	0	24	0
255	Eldorado, *Saline*..........	1941	20	0	1,000	1,000	0	0	2	2	0	0	2	0
256	Lakewood, *Shelby*....	1941	20	0	8,000	8,000	0	0	2	2	0	0	2	0
257			10	0	*x*	*x*	0	0	1	1	0	0	1	0
258			10	0	*x*	*x*	0	0	1	1	0	0	1	0
259	Stewardson, *Shelby*........	1939	30	0	22,000	11,000	0	0	3	0	0	0	3	0
260	East Keensburg, *Wabash* ...	1939	20	0	*x*	*x*	0	0	2	0	0	0	2	0
261	Keensburg Consolidated, *Wabash*	1939	2,230	0	6,062,000	2,273,000	0	0	302	45	7	1	294	0
262			*x*	0	*x*	*x*	0	0	16	1	0	1	15	0

TABLE 1.—(*Continued*)

	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.			Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
Line Number	Flowing	Artificial Lift	Initial	Avg. at End of 1941	Repressuring Operation[d]	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
209	0	0													A	Dev	3,133
210	0	0	250	245				Bridgeport	Pen	S	Por	760	793	15			
211	0	0	395	280				Buchanan	Pen	S	Por	1,108	1,119	11			
212	0	3	*x*	*x*		40.1	*x*	Bethel	MisU	S	Por	1,765	1,773	8	A	MisL	1,962
213	0	7	*x*	*x*		31.7	*x*	Buchanan	Pen	S	Por	1,369	1,397	11	D	Pen	1,405
214	0	3	*x*	*x*		20.3	*x*	Pennsylvanian	Pen	S	Por	443	462	10	D	Pen	462
215	0	2	*x*	*x*		37.1	*x*	Bethel, Rosiclare	MisU, MisL	S	Por	1,931	2,110	21	A	Dev	3,692
216	0	113													A	Dev	2,956
217	0	110	*x*	35		39.5	*x*	Bethel	MisU	S	Por	1,424	1,449	25			
218	0	3	*x*	*x*		40.9	0.31	Rosiclare	MisL	S	Por	1,562	1,572	10			
219	0	56													A	MisL	1,737
220	0	51	*x*	265		36.1	0.23	Cypress	MisU	S	Por	1,340	1,360	20			
221	0	5	*x*	*x*		36.1	0.23	Bethel	MisU	S	Por	1,466	1,478	12			
222	22	2,336			PM										A	St. Peter	5,655
223	0	439	*x*	*x*		38.5	0.20	Bethel	MisU	S	Por	1,797	1,838	40			
224	0	149	*x*	*x*		38.6	0.21	Aux Vases	MisU	S	Por	1,813	1,865	28			
225	0	523	*x*	*x*		39.0	*x*	McClosky	MisL	L	Por	1,975	2,048	17			
226	0	8	*x*	*x*		39.0	*x*	Salem	MisL	L	Por	2,156	2,222	17			
227	1	438	*x*	*x*		42.1	0.28	Devonian	Dev	L	Por	3,350	3,444	60			
228	20	79	*x*	*x*		42.0	*x*	Trenton	Ord	L	Por	4,500	4,625	50			
229	1	700						[33]									
230	0	54													D	Dev	3,547
231	0	5	*x*	*x*		39.0	*x*	Bethel	MisU	S	Por	1,928	1,948	20			
232	0	15	*x*	*x*		39.0	*x*	Aux Vases	MisU	S	Por	2,003	2,038	30			
233	0	28	*x*	*x*		39.4	0.21	McClosky	MisL	L	Por	2,134	2,149	15			
234	0	6	*x*	*x*		41.0	*x*	Devonian	Dev	L	Por	3,490	3,505	15			
235	0	24	*x*	100		38.2	0.21	Bethel	MisU	S	Por	1,462	1,479	8	D	"Trenton"	4,100
236	0	2	*x*	*x*		33.5	*x*	Pennsylvanian	Pen	S	Por	580	598	18	D	Pen	598
237	0	4	*x*	*x*		34.1	*x*	Pennsylvanian	Pen	S	Por	611	625	14	D	Dev	1,784
238	0	1	*x*	100		37.8	*x*	McClosky	MisL	L	Por	3,120	3,200	8	D	MisL	3,200
239	0	6													D	MisL	3,170
240	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,930	2,970	10			
241	0	1	*x*	*x*		*x*	*x*	Levias	MisL	L	Por	3,070	3,080	10			
242	0	4	*x*	*x*		38.1	*x*	McClosky	MisL	L	Por	3,130	3,170	6			
243	11	226													A	Dev	4,584
244	0	1	*x*	*x*		37.0	*x*	Cypress	MisU	S	Por	2,570	2,590	23			
245	0	1	*x*	*x*		38.0	*x*	Aux Vases	MisU	S	Por	2,705	2,738	10			
246	11	222	*x*	*x*		38.4	0.17	McClosky	MisL	L	Por	2,869	2,920	13			
247	0	2						[33]							A	MisL	3,201
248	0	231															
249	0	88	*x*	*x*		38.0	0.27	Cypress	MisU	S	Por	2,544	2,639	20			
250	0	143	*x*	*x*		39.0	*x*	McClosky	MisL	L	Por	2,957	3,003	10			
251	0	34	*x*	*x*		37.2	0.19	McClosky	MisL	L	Por	3,052	3,073	9	A	MisL	3,222
252	0	4	*x*	*x*		37.0	0.19	McClosky	MisL	L	Por	3,012	3,068	6	D	MisL	3,120
253	0	3	*x*	*x*		40.0	*x*	McClosky	MisL	L	Por	3,025	3,040	8	D	MisL	3,040
254	5	19	*x*	*x*		39.5	*x*	McClosky	MisL	L	Por	3,120	3,130	12	A	MisL	3,130
255	0	2	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	2,943	2,950	5	A	MisL	3,000
256	0	2													D	MisL	1,874
257	0	1	*x*	*x*		29.6	*x*	Bethel	MisU	S	Por	1,692	1,700	8			
258	0	1	*x*	*x*		32.0	*x*	Aux Vases	MisU	S	Por	1,723	1,735	9			
259	0	3	*x*	*x*		37.8	0.18	Aux Vases	MisU	S	Por	1,942	1,969	5	D	MisU	1,969
260	0	2	*x*	*x*		37.6	0.26	McClosky	MisL	L	Por	2,703	2,714	6	D	MisL	2,714
261	0	294													A	MisL	3,058
262	0	15	*x*	*x*		38.0	*x*	Biehl	Pen	S	Por	1,719	1,733	14			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941: Completed	During 1941: Abandoned	Temporarily Shut Down	End of 1941: Producing Oil[e]	End of 1941: Producing Gas[e]
263			*x*	0	*x*	*x*	0	0	2	0	0	0	2	0
264			*x*	0	*x*	*x*	0	0	4	0	0	0	4	0
265			*x*	0	*x*	*x*	0	0	7	6	0	0	7	0
266			*x*	0	*x*	*x*	0	0	238	18	7	0	231	0
267			*x*	0	*x*	*x*	0	0	6	4	0	0	6	0
268			*x*	0	*x*	*x*	0	0	2	2	0	0	2	0
269			*x*	0	*x*	*x*	0	0	19	6	0	0	19	0
270									8	8	0	0	8	0
271	Maud, *Wabash*............	1940	250	0	248,000	205,000	0	0	20	11	2	1	17	0
272			*x*	0	*x*	*x*	0	0	2	2	0	0	2	0
273			*x*	0	*x*	*x*	0	0	1	0	0	0	1	0
274			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
275			*x*	0	*x*	*x*	0	0	15	7	2	1	12	0
276									1	1	0	0	1	0
277	Mt. Carmel, *Wabash*.......	1940	1,140	0	1,720,000	1,695,000	0	0	189	185	2	0	187	0
278			*x*	0	*x*	*x*	0	0	29	29	2	0	27	0
279			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
280			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
281			*x*	0	*x*	*x*	0	0	122	119	0	0	122	0
282			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
283			*x*	0	*x*	*x*	0	0	2	1	0	0	2	0
284			*x*	0	*x*	*x*	0	0	23	23	0	0	23	0
285									10	10	0	0	10	0
286	Mt. Carmel West, *Wabash*..	1939	20	0	*x*	*x*	0	0	2	0	0	0	1	0
287	Patton, *Wabash*............	1940[28]	40	0	2,000	2,000	0	0	4	1	0	0	4	0
288			30	0	*x*	*x*	0	0	3	0	0	0	3	0
289			10	0	2,000	2,000	0	0	1	1	0	0	1	0
290	Lancaster, *Wabash, Lawrence*	1940	320	0	440,000	99,000	0	0	28	0	4	1	22	0
291	Cordes, *Washington*........	1939	1,430	0	1,724,000	540,000	0	0	128	0	0	0	127	0
292	Dubois, *Washington*........	1939	120	0	57,000	36,000	0	0	9	5	0	0	9	0
293	Irvington, *Washington*......	1940	700	0	1,554,000	1,044,000	0	0	74	35	0	0	74	0
294					*x*	*x*	0	0	66	33	0	0	66	0
295					*x*	217,000	0	0	7	1	0	0	7	0
296									1	1	0	0	1	0
297	McKinley, *Washington*.....	1940	60	0	91,000	87,000	0	0	6	5	0	0	6	0
298			50	0	*x*	*x*	0	0	5	4	0	0	5	0
299			10	0	*x*	*x*	0	0	1	1	0	0	1	0
300	Barnhill, *Wayne*............	1939	870	0	1,460,000	230,000	0	0	64	1	1	0	62	0
301			*x*	0	*x*	*x*	0	0	61	1	1	0	59	0
302			*x*	0	*x*	*x*	0	0	1	0	0	0	1	0
303									2	0	0	0	2	0
304	Boyleston, *Wayne*..........	1938	1,590	0	2,351,000	824,000	0	0	100	17	0	0	100	0
305			10	0	*x*	*x*	0	0	1	0	0	0	1	0
306			1,590	0	*x*	*x*	0	0	98	17	0	0	98	0
307									1	0	0	0	1	0
308	Cisne, *Wayne*..............	1937	960	0	2,462,000	222,000	0	0	47	0	2	0	45	0
309			*x*	0	*x*	*x*	0	0	2	0	0	0	2	0
310			*x*	0	*x*	*x*	0	0	1	0	0	0	1	0
311			*x*	0	*x*	*x*	0	0	44	0	2	0	42	0
312	Geff, *Wayne*...............	1941	10	0	4,000	4,000	0	0	1	1	0	0	1	0
313	Goldengate, *Wayne*.........	1939	60	0	*x*	*x*	0	0	6	3	0	0	4	0
314			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
315			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
316			*x*	0	*x*	*x*	0	0	4	1	0	0	2	0
317	Johnsonville, *Wayne*........	1941	3,780	0	5,532,000	5,532,000	0	0	217	217	0	0	217	0
318			*x*	0	*x*	*x*	0	0	19	19	0	0	19	0
319			*x*	0	*x*	*x*	0	0	196	196	0	0	196	0
320									2	2	0	0	2	0

[28] Biehl sand production since 1936, formerly included in the Allendale pool.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
263	0	2	*x*	*x*		*x*	*x*	Clore	MisU	S	Por	1,811	1,823	9			
264	0	4	*x*	*x*		*x*	*x*	Palestine	MisU	S	Por	1,830	1,846	16			
265	0	7	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	2,060	2,075	15			
266	0	231	*x*	*x*		38.6	0.29	Cypress	MisU	S	Por	2,444	2,462	18			
267	0	6	*x*	*x*		36.6	*x*	Bethel	MisU	S	Por	2,570	2,588	18			
268	0	2	*x*	*x*		*x*	*x*	Aux Vases	MisU	S	Por	2,760	2,790	30			
269	0	19	*x*	*x*		37.9	0.38	McClosky	MisL	L	Por	2,790	2,797	7			
270	0	8						33									
271	0	17													D	MisL	2,658
272	0	2	*x*	*x*		*x*	*x*	Waltersburg	MisU	S	Por	1,935	1,956	21			
273	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,120	2,132	12			
274	0	1	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	2,639	2,650	9			
275	0	12	*x*	*x*		38.0	0.30	McClosky	MisL	L	Por	2,650	2,658	8			
276	0	1						33									
277	0	187													A	MisL	2,411
278	0	27	*x*	*x*		*x*	*x*	Biehl	Pen	S	Por	1,450	1,464	14			
279	0	1	*x*	*x*		*x*	*x*	Palestine	MisU	S	Por	1,540	1,550	10			
280	0	1	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	1,790	1,794	4			
281	0	122	*x*	*x*		38.4	*x*	Cypress	MisU	S	Por	2,033	2,048	15			
282	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,100	2,115	15			
283	0	2	*x*	*x*		36.6	0.36	Rosiclare	MisL	S	Por	2,360	2,364	4			
284	0	23	*x*	*x*		38.4	0.42	McClosky	MisL	L	Por	2,370	2,380	10			
285	0	10															
286	0	1	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	1,940	1,955	15	D	MisL	2,556
287	0	4													A	MisL	2,313
288	0	3	*x*	*x*		*x*	*x*	Biehl	Pen	S	Por	1,470	1,485	15			
289	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	2,309	2,313	4			
290	0	22	*x*	*x*		39.8	0.28	McClosky	MisL	L	Por	2,683	2,700	9	A	MisL	2,700
291	0	127	*x*	*x*		37.4	0.19	Bethel	MisU	S	Por	1,259	1,285	17	A	MisL	1,550
292	0	9	*x*	100		38.0	0.26	Bethel	MisU	S	Por	1,359	1,370	11	D	Dev	3,537
293	0	74													A	Dev	3,150
294	0	66	*x*	*x*		37.6	0.16	Bethel	MisU	S	Por	1,537	1,550	10			
295	0	7	*x*	*x*		39.0	*x*	Devonian	Dev	L	Por	3,092	3,150	5			
296	0	1						33									
297	0	6													D	Dev	2,567
298	0	5	*x*	*x*		44.1	*x*	Bethel	MisU	S	Por	982	996	14			
299	0	1	*x*	*x*		41.7	*x*	Devonian	Dev	L	Por	2,250	2,272	4			
300	0	62													A	MisL	3,855
301	0	59	*x*	*x*		37.6	0.17	McClosky	MisL	L	Por	3,385	3,411	11			
302	0	1	*x*	*x*		*x*	*x*	Salem	MisL	L	Por	3,792	3,855	*y*			
303	0	2						33									
304	0	100													A	MisL	3,384
305	0	1	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	3,273	3,277	4			
306	0	98	*x*	*x*		40.2	0.14	McClosky	MisL	L	Por	3,250	3,277	14			
307	0	1						33									
308	0	45													A	St. Peter	7,207
309	0	2	*x*	*x*		38.5	*x*	Aux Vases	MisU	S	Por	2,982	3,029	13			
310	0	1	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	3,010	3,160	4			
311	0	42	*x*	*x*		35.8	0.24	McClosky	MisL	L	Por	3,121	3,178	15			
312	0	1	*x*	*x*		29.4	*x*	McClosky	MisL	L	Por	3,135	3,180	3	D	MisL	3,180
313	0	4													D	Dev	5,645
314	0	1	*x*	*x*		*x*	*x*	Aux Vases	MisU	S	Por	3,238	3,350	12			
315	0	1	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	3,318	3,345	5			
316	0	2	*x*	*x*		34.4	0.18	McClosky	MisL	L	Por	3,377	3,399	7			
317	0	217													A	MisL	3,150
318	0	19	*x*	600		39.4	*x*	Aux Vases	MisU	S	Por	2,980	3,040	12			
319	0	196	*x*	1,100		39.4	0.16	McClosky	MisL	L	Por	3,070	3,150	15			
320	0	2						33									

TABLE 1.—*(Continued)*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
321	Leech Township, *Wayne*	1938	240	0	302,000	70,000	0	0	14	0	0	0	14	0
322	Mt. Erie, *Wayne*	1938	10	0	11,000	1,000	0	0	1	0	0	0	1	0
323	Mayberry, *Wayne*	1941	20	0	6,000	6,000	0	0	2	2	0	0	2	0
324	North Aden, *Wayne*	1938	1,100	0	2,486,000	551,000	0	0	65	0	0	0	61	0
325	Rinard, *Wayne*	1937[29]	10	0	15,000	0	0	0	1	0	0	0	0	0
326	South Mt. Erie, *Wayne*	1939[30]	10	0	7,000	0	0	0	1	0	0	0	0	0
327	Sims, *Wayne*	1941	50	0	41,000	41,000	0	0	4	4	0	0	4	0
328			*x*	0	*x*	*x*			2	2	0	0	2	0
329			*x*	0	*x*	*x*			2	2	0	0	2	0
330	Aden, *Wayne, Hamilton*	1938	370	0	389,000	145,000	0	0	9	1	0	0	9	0
331	Burnt Prairie, *White*	1940	270	0	254,000	108,000	0	0	20	2	0	0	20	0
332			*x*	0	*x*	*x*	0	0	2	0	0	0	2	0
333			*x*	0	*x*	*x*	0	0	18	2	0	0	18	0
334	Calvin West, *White*	1939	10	0	*x*	*x*	0	0	1	0	0	0	1	0
335	Carmi, *White*	1940	10	0	2,000	1,500	0	0	1	0	0	0	1	0
336	Centerville, *White*	1940	60	0	115,000	66,000	0	0	5	2	0	0	5	0
337	Centerville East, *White*	1941	70	0	18,000	18,000	0	0	6	6	0	0	6	0
338			*x*	0	*x*	*x*	0	0	4	4	0	0	4	0
339			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
340			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
341	Epworth, *White*	1941	40	0	14,000	14,000	0	0	4	4	0	0	4	0
342			10	0	*x*	*x*	0	0	1	1	0	0	1	0
343			20	0	*x*	*x*	0	0	2	2	0	0	2	0
344			10	0	*x*	*x*	0	0	1	1	0	0	1	0
345	Grayville West, *White*	1941	30	0	9,000	9,000	0	0	3	3	0	0	3	0
346			10	0	*x*	*x*	0	0	1	1	0	0	1	0
347			20	0	*x*	*x*	0	0	2	2	0	0	2	0
348	Herald, *White*	1940	70	0	23,000	19,000	0	0	5	2	0	0	5	0
349			*x*	0	*x*	*x*	0	0	2	0	0	0	2	0
350			*x*	0	*x*	*x*	0	0	3	2	0	0	3	0
351	Iron, *White*	1940	760	0	1,918,000	807,000	0	0	63	17	0	0	63	0
352			*x*	0	*x*	*x*	0	0	5	4	0	0	5	0
353			*x*	0	*x*	*x*	0	0	33	6	0	0	33	0
354			*x*	0	*x*	*x*	0	0	2	1	0	0	2	0
355			*x*	0	*x*	*x*	0	0	20	3	0	0	20	0
356									3	3	0	0	3	0
357	Maunie, *White*	1941	20	0	4,000	4,000	0	0	2	2	0	0	2	0
358	Maunie North, *White*	1941	30	0	6,000	6,000	0	0	3	3	0	0	3	0
359			10	0	*x*	*x*	0	0	1	1	0	0	1	0
360			20	0	*x*	*x*	0	0	2	2	0	0	2	0
361	Maunie South, *White*	1941	480	0	374,000	374,000	0	0	52	52	0	0	52	0
362			*x*	0	*x*	*x*	0	0	4	4	0	0	4	0
363			*x*	0	*x*	*x*	0	0	30	30	0	0	30	0
364			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
365			*x*	0	*x*	*x*	0	0	8	8	0	0	8	0
366			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
367			*x*	0	*x*	*x*	0	0	5	5	0	0	5	0
368			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
369									2	2	0	0	2	0
370	New Harmony Consolidated, *White*	1939	5,008	0	11,706,000	10,180,000	0	0	648	445	1	0	647	0
371			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
372			*x*	0	*x*	*x*	0	0	16	2	0	0	16	0
373			*x*	0	*x*	*x*	0	0	22	13	0	0	22	0
374			*x*	0	*x*	*x*	0	0	80	50	0	0	80	0
375			*x*	0	*x*	*x*	0	0	11	5	0	0	11	0

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[29] Abandoned 1939.

[30] Abandoned 1941.

TABLE I.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
321	0	14	*x*	*x*		39.0	0.19	McClosky	MisL	L	Por	3,413	3,453	11	D	MisL	3,485
322	0	1	*x*	*x*		39.8	0.18	McClosky	MisL	L	Por	3,080	3,092	*y*	D	MisL	3,135
323	0	2	*x*	*x*		38.0	*x*	McClosky	MisL	L	Por	3,340	3,380	7	D	MisL	3,380
324	0	61	*x*	*x*		39.0	0.17	McClosky	MisL	L	Por	3,321	3,341	12	A	Dev	5,393
325	0	0	*x*	*x*		38.5	*x*	McClosky	MisL	L	Por	3,144	3,154	5	D	MisL	3,154
326	0	0	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,129	3,206	11	D	MisL	3,206
327	0	4													A	MisL	3,220
328	0	2	*x*	1,100		38.9	*x*	Aux Vases	MisU	S	Por	3,030	3,045	15			
329	0	2	*x*	*x*		39.1	*x*	McClosky	MisL	L	Por	3,170	3,220	8			
330	0	9	*x*	*x*		40.0	*x*	McClosky	MisL	L	Por	3,287	3,337	7	A	MisL	3,460
331	0	20													D	MisL	3,432
332	0	2	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	3,260	3,404	9			
333	0	18	*x*	*x*		37.0	0.28	McClosky	MisL	L	Por	3,425	3,436	11			
334	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,191	3,201	*y*	D	MisL	3,201
335	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,148	3,167	4	D	MisL	3,167
336	0	5	*x*	*x*		38.0	*x*	McClosky	MisL	L	Por	3,355	3,373	4	D	MisL	3,373
337	0	6													D	MisL	3,276
338	0	4	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	2,530	2,545	15			
339	0	1	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	2,915	2,925	10			
340	0	1	*x*	*x*		40.0	*x*	McClosky	MisL	L	Por	3,264	3,276	12			
341	0	4													D	MisL	3,148
342	0	1	*x*	*x*		*x*	*x*	Degonia	MisU	S	Por	2,092	2,108	6			
343	0	2	*x*	*x*		36.2	*x*	Clore	MisU	S	Por	2,072	2,109	18			
344	0	1	*x*	*x*		*x*	*x*	Palestine	MisU	S	Por	2,099	2,188	14			
345	0	3													D	MisL	3,273
346	0	1	*x*	*x*		37.0	*x*	Cypress	MisU	S	Por	2,870	2,890	20			
347	0	2	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,172	3,273	8			
348	0	5													A	MisL	3,060
349	0	2	*x*	*x*		28.0	*x*	Pennsylvanian	Pen	S	Por	1,565	1,571	6			
350	0	3	*x*	*x*		35.0	*x*	Tar Springs	MisU	S	Por	2,259	2,276	18			
351	0	63													A	MisL	3,142
352	0	5	*x*	*x*		36.0	*x*	Tar Springs	MisU	S	Por	2,425	2,440	6			
353	0	33	*x*	*x*		38.4	0.30	Hardinsburg	MisU	S	Por	2,537	2,556	18			
354	0	2	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	2,708	2,753	24			
355	0	20	*x*	*x*		39.0	0.20	McClosky	MisL	L	Por	3,061	3,142	10			
356	0	3						33									
357	0	2	*x*	*x*		38.0	*x*	Palestine	MisU	S	Por	2,012	2,018	6	D	MisL	3,049
358	0	3													D	MisL	3,092
359	0	1	*x*	*x*		36.5	*x*	Bethel	MisU	S	Por	2,826	2,847	21			
360	0	2	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	3,075	3,092	6			
361	0	52													A	MisL	2,873
362	0	4	*x*	50		37.0	*x*	Pennsylvanian	Pen	S	Por	1,455	1,480	25			
363	0	30	*x*	150		38.0	*x*	Palestine	MisU	S	Por	2,020	2,038	18			
364	0	1	*x*	*x*		*x*	*x*	Waltersburg	MisU	S	Por	2,208	2,217	9			
365	0	8	*x*	175		38.0	*x*	Tar Springs	MisU	S	Por	2,254	2,268	14			
366	0	1	*x*	200		38.0	*x*	Cypress	MisU	S	Por	2,561	2,569	8			
367	0	5	*x*	250		39.0	*x*	Aux Vases	MisU	S	Por	2,844	2,866	22			
368	0	1	*x*	*x*		*x*	*x*	McClosky	MisL	L	Por	2,871	2,873	2			
369	0	2															
370	3	644													A	MisL	3,107
371	0	1	*x*	*x*		*x*	*x*	Biehl	Pen	S	Por	1,830	1,870	40			
372	0	16	*x*	*x*		37.6	0.40	Waltersburg	MisU	S	Por	2,156	2,197	20			
373	0	22	*x*	*x*		38.0	*x*	Tar Springs	MisU	S	Por	2,225	2,296	15			
374	0	80	*x*	*x*		39.0	*x*	Cypress	MisU	S	Por	2,561	2,605	25			
375	0	11	*x*	*x*		38.0	*x*	Paint Creek Stray	MisU	S	Por	2,659	2,679	20			

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
376			*x*	0	*x*	*x*	0	0	117	81	1	0	116	0
377			*x*	0	*x*	*x*	0	0	145	131	0	0	145	0
378			*x*	0	*x*	*x*	0	0	2	1	0	0	2	0
379			*x*	0	*x*	*x*	0	0	93	43	0	0	93	0
380									161	118	0	0	161	0
381	New Harmony South, *White*.	1941	60	0	24,000	24,000	0	0	4	4	0	0	4	0
382			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
383			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
384			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
385			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
386	New Haven, *White*.........	1941	150	0	172,000	172,000	0	0	19	19	0	0	19	0
387			*x*	0	*x*	*x*	0	0	4	4	0	0	4	0
388			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
389			*x*	0	*x*	*x*	0	0	6	6	0	0	6	0
390			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
391			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
392									4	4	0	0	4	0
393	Phillipstown' *White*........	1939	150	0	125,000	64,000	0	0	11	5	0	0	11	0
394			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
395			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
396			*x*	0	*x*	*x*	0	0	2	0	0	0	2	0
397			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
398			*x*	0	*x*	*x*	0	0	4	0	0	0	4	0
399	Roland, *White*.............	1940	800	0	1,096,000	1,093,000	0	0	92	91	0	4	88	0
400			*x*	0	*x*	*x*	0	0	43	43	0	0	43	0
401			*x*	0	*x*	*x*	0	0	3	2	0	1	2	0
402			*x*	0	*x*	*x*	0	0	4	4	0	0	4	0
403			*x*	0	*x*	*x*	0	0	7	7	0	0	7	0
404			*x*	0	*x*	*x*	0	0	11	11	0	3	8	0
405									24	24	0	0	24	0
406	Stokes, *White*..............	1939	280	0	256,000	89,000	0	0	16	5	1	1	14	0
407			*x*	0	*x*	*x*	0	0	3	3	0	1	2	0
408			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
409			*x*	0	*x*	*x*	0	0	12	1	1	0	11	0
410	Storms, *White*.............	1939	1,470	0	2,947,000	1,399,000	0	0	155	25	0	4	151	0
411			*x*	0	*x*	*x*	0	0	151	21	0	4	147	0
412			*x*	0	*x*	*x*	0	0	1	1	0	0	1	0
413			*x*	0	*x*	*x*	0	0	3	3	0	0	3	0
414	Mill Shoals, *White*, *Hamilton*	1939	850	0	1,658,000	947,000	0	0	93	43	0	0	93	0
415			*x*	0	*x*	*x*	0	0	73	40	0	0	73	0
416			*x*	0	*x*	*x*	0	0	17	3	0	0	17	0
417									3	0	0	0	3	0
418	Total for fields discovered after Jan. 1, 1937[31]		97,483	1,630	385,526,000	128,994,000	2,818.5	863.0	10,899	2,819	158	67	10,496	48
419	Total for Illinois[32]		196,083	17,460	833,059,000	134,139,000	5,206.5	876.4	31,615	2,925	414	376	23,427	55

[31] Total of lines 96 to 417 inclusive.

[32] Total of lines 95 and 418.

DEEP TESTS DURING 1941 (TABLE 6)

The St. Peter sandstone was tested in the Salem, Louden and Bartelso fields but was not found productive. There was slight saturation in the "Trenton," the top of which was encountered at a depth of 3824 ft. in the Carter Oil Company's J. Brauer 6-D well, Louden field, but it was not commercial.

The Devonian limestone was tested in the Clay City Consolidated field by the Pure Oil Company's Moseley 3-B well but it was not productive.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
376	0	116	*x*	*x*		38.0	*x*	Bethel	MisU	S	Por	2,684	2,751	25			
377	2	143	*x*	*x*		39.0	*x*	Aux Vases	MisU	S	Por	2,820	2,840	20			
378	0	2	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	2,906	2,920	15			
379	1	92	*x*	*x*		39.2	0.20	McClosky	MisL	L	Por	2,892	2,919	8			
380	0	161						[33]									
381	0	4													A	MisL	3,059
382	0	1	*x*	*x*		*x*	*x*	Waltersburg	MisU	S	Por	2,262	2,282	20			
383	0	1	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	2,355	2,373	16			
384	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,820	2,830	10			
385	0	1	*x*	*x*		38.0	*x*	McClosky	MisL	L	Por	3,011	3,020	8			
386	0	19													A	MisL	2,850
387	0	4	*x*	*x*		38.0	*x*	Tar Springs	MisU	S	Por	2,115	2,125	10			
388	0	1	*x*	*x*		38.0	*x*	Hardinsburg	MisU	S	Por	2,246	2,251	5			
389	0	6	*x*	*x*		38.0	*x*	Cypress	MisU	S	Por	2,436	2,448	12			
390	0	3	*x*	*x*		39.0	*x*	Aux Vases	MisU	S	Por	2,717	2,732	15			
391	0	1	*x*	*x*		38.0	*x*	McClosky	MisL	L	Por	2,845	2,850	5			
392	0	4						[33]									
393	0	11													A	Dev	5,349
394	0	1	*x*	*x*		*x*	*x*	Degonia	MisU	S	Por	1,997	2,007	10			
395	0	1	*x*	*x*		*x*	*x*	Tar Springs	MisU	S	Por	2,293	2,320	27			
396	0	2	*x*	*x*		3904	*x*	Aux Vases	MisU	S	Por	2,942	2,964	8			
397	0	3	*x*	*x*		*x*	*x*	Rosiclare	MisL	S	Por	2,955	2,967	10			
398	0	4	*x*	*x*		38.2	0.21	McClosky	MisL	L	Por	2,994	3,004	10			
399	3	85													A	Dev	5,225
400	0	43	*x*	600		32.0	*x*	Waltersburg	MisU	S	Por	2,159	2,174	15			
401	0	2	*x*	*x*		32.0	*x*	Tar Springs	MisU	S	Por	2,231	2,243	12			
402	0	4	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	2,551	2,568	17			
403	0	7	*x*	*x*		39.0	*x*	Bethel	MisU	S	Por	2,724	2,741	17			
404	0	8	*x*	800		*x*	*x*	Aux Vases	MisU	S	Por	2,880	2,898	18			
405	3	21						[33]									
406	0	14													A	MisL	3,150
407	0	2	*x*	*x*		*x*	*x*	Paint Creek Stray	MisU	S	Por	2,760	2,805	27			
408	0	1	*x*	*x*		*x*	*x*	Bethel	MisU	S	Por	2,813	2,827	8			
409	0	11	*x*	*x*		35.8	0.26	McClosky	MisL	L	Por	3,077	3,124	12			
410	1	150			PM										A	MisL	3,082
411	1	146	*x*	125		32.1	0.28	Waltersburg	MisU	S	Por	2,234	2,285	18			
412	0	1	*x*	*x*		*x*	*x*	Cypress	MisU	S	Por	2,656	2,685	10			
413	0	3	*x*	*x*		*x*	*x*	Paint Creek Stray	MisU	S	Por	2,807	2,832	14			
414	0	93													A	MisL	3,316
415	0	73	*x*	*x*		39.8	0.14	Aux Vases	MisU	S	Por	3,221	3,241	20			
416	0	17	*x*	*x*		38.0	0.16	McClosky	MisL	L	Por	3,316	3,391	14			
417	0	3						[33]									
418	372	10,124															
419	372	23,055															

DEVELOPMENT

Most of the new discoveries and development during 1941 took place in White, Hamilton, Wayne, and Wabash Counties, in the southeastern part of the state. In White County alone, 839 wells were completed, of which 728 were producing wells (Table 7). Field development during the year was principally in the Johnsonville, Rural Hill, and Benton fields, as mentioned; in the New Harmony Consolidated field, White County, and the Woodlawn field, Jefferson County.

TABLE 2.—*Discovery Wells of New Fields in Illinois in 1941*

Field, *County*	Company and Farm	Location	Total Depth, Ft.	Depth to Top, Ft.	Producing Formation	Initial Production, Bbl.	Date of Completion of Discovery Well	Number of Wells in Field Dec. 31, 1941
Alma, *Marion*	Swan-King, Kotva	C S SW NW 36-4N-2E	2,101	2,070	Rosiclare sandstone	439	9-23-41	2
Benton, *Franklin*	Adkins, Orient Coal Co. No. 1	NE SW SE 24-6S-2E	2,148	2,111	Tar Springs sandstone	374	1-21-41	222
Benton N., *Franklin*	Mohawk Drilling Co., Stuart No. 1	NE NE NE 11-6S-2E	2,794	2,789	Rosiclare sandstone	380	9-16-41	6
Bone Gap, *Edwards*	Tidewater Assoc. Oil Co., Gawthorp No. 1	NE NE NE 13-1S-10E	3,325	3,266	McClosky limestone	46	2-4-41	4
Bonpas, *Richland*	Case-Pomeroy, Bowers No. 1	SW SW SE 34-3N-14W	3,12	3,118	McClosky limestone	260	5-27-41	1
Bonpas West, *Richland*	Craft, Daubs No. 1	E SW NE 8-2N-14W	3,171	3,144	McClosky limestone	940	8-26-41	7
Boulder, *Clinton*	Texas Company, Gray No. 1	S NW SE 35-3N-2W	2,655	2,570	Devonian limestone	17[2]	9-30-41	1
Bungay, *Hamilton*	Woodriver Dev. Co., Walker No. 1	SW NE NW 26-4S-7E	3,290	3,272	Aux Vases sandstone	25	3-4-41	1
Carlinville N., *Macoupin*	Mudgett, Goebelt No. 1	W NE SE 20-10N-7W	447	436	Lower Pennsylvanian sandstone	10	12-2-41	3
Centerville E., *White*	Yingling et al., Shepard No. 1	NE NE NE 5-4S-10E	2,925	2,887	Cypress sandstone	60	9-9-41	6
Clay City W., *Clay*	Williams, Nolan No. 1	C S SE NW 10-2N-7E	3,182	3,064	McClosky limestone	3,608	12-16-41	2
Cooks Mills, *Coles*	Carter Oil Co., Haybrook No. 1	C E SE SW 2-13N-7E	1,842	1,830	Aux Vases sandstone	30	12-9-41	1
Dahlgren, *Hamilton*	Duncan, Zeller No. 1	SE NE NE 34-3S-5E	3,359	3,337	McClosky limestone	132	1-14-41	42
Eldorado, *Saline*	Thompson Drill. Co., Reich No. 1	NE SW NE 8-8S-7E	2,998	2,943	McClosky limestone	92	8-26-41	2
Elkville, *Jackson*	Wiser, Overholt No. 1	C SE SW 22-7S-1W	2,028	2,000	Bethel sandstone	5	6-10-41	1
Ellery, *Edwards*	Martin, Lester No. 1	W SW SW 19-2S-10E	3,351	3,341	McClosky limestone	62	5-20-41	2
Epworth, *White*	Catlett, Calvert No. 1	SE SE NW 32-5S-10E	2,188	2,099	Palestine sandstone	90	9-9-41	4
Grayville W., *White*	Wall and Mitchell, Kershaw No. 1	SW SW NE 22-3S-10E	2,897	2,853	Cypress sandstone	53	8-5-41	3
Geff, *Wayne*	Pure Oil Co., Johnson No. A-1	W SE NE 12-1S-7E	3,180	3,135	McClosky limestone	62	8-19-41	1
Inman N., *Gallatin*	Blackstock, Cox No. 1	NE NW SW 2-8S-9E	3,020		McClosky limestone	40	7-8-41	2
Johnsonville, *Wayne*	Wiser Oil Co., Hilliard No. 1	S SE SW 27-1N-6E	3,085	2,992	McClosky limestone	2,406	7-15-41	217
Lakewood, *Shelby*	Sloan, Cutler No. 1	SE SE NE 12-10N-2E	1,735	1,723	Aux Vases sandstone	37	4-29-41	2
Maunie, *White*	Halbert, Hueble No. A-1	NE NW SW 7-6S-11E	2,018	2,012	Palestine sandstone	35	4-8-41	3
Maunie N., *White*	Continental, Ackerman No. 1	NE NW NE 25-5S-10E	2,838	2,824	Bethel sandstone	20	6-10-41	3
Maunie S., *White*	Cherry and Kidd, Karch No. 1	SW NW NE 24-6S-10E	2,872	2,841	Aux Vases sandstone	141	5-13-41	52
Mayberry, *Wayne*	Texas Co., Draper No. 1	C N NW SW 8-3S-6E	3,380	3,352	McClosky limestone	75	8-26-41	2
New Harmony S., *White*	Rhodes, Golden No. 1	NW NW SE 29-5S-14W	2,282	2,218	Waltersburg sandstone	112	1-28-41	4
New Haven, *White*	Hiawatha, Stinson No. 1	SW SW NE 19-7S-11E	2,129	2,115	Tar Springs sandstone	107	3-25-41	19
Parkersburg, *Richland*	Ohio Oil Co., Koertge No. 1	SE SE NW 29-2N-14W	3,129	3,117	McClosky limestone	1,459	8-19-41	24
Patoka E., *Marion*	Obering and Phillips, Thalman No. 1	NW NW NW 35-4N-1E	1,360	1,349	Cypress sandstone	48	1-28-41	56
Patton,[1] *Wabash*	Fotiades, Mason No. 1	SW SE NW 27-1N-12W	2,316	2,309	McClosky limestone	170	11-18-41	4
Posey, *Clinton*	Ashoff, Lampen No. 1	NW NW NW 16-1N-2W	1,110	1,105	Cypress sandstone	29	4-1-41	2
Ruark, *Lawrence*	DeKalb Agr. Assoc., King No. 1	S SW NE 8-2N-12W	1,531	1,514	Buchanan sandstone	57	10-21-41	1
Rural Hill, *Hamilton*	Shell, Ventrees No. 1	SW SW SE 12-6S-5E	3,194	3,188	McClosky limestone	794	8-5-41	94
St. Francisville E., *Lawrence*	Sinclair-Wyoming, All States Life Ins. Co. No. 1	SE SE NW 22-2N-11W	1,762	1,747	Bethel sandstone	40	10-21-41	3
St. Paul, *Fayette*	Luttrell, Ford No. 1	NE NE NW 31-5N-3E	1,891	1,876	Bethel sandstone	41	10-14-41	2
Stringtown, *Richland*	Nolf et al., Nuding No. 1	NW SW NW 6-4N-14W	3,041	3,028	McClosky limestone	190	11-11-41	3
Ste. Marie, *Jasper*	Craft and Powers, Wade No. 1	W SW NW 5-5N-14W	2,935	2,832	McClosky limestone	500	11-25-41	3
Sailor Springs, *Clay*	Robinson, Tolliver No. 1	SW NW SE 26-4N-7E	2,341	2,327	Tar Springs sandstone	292	6-3-41	25
Sims, *Wayne*	Bell Bros., Fuhrer No. 1	W NE NW 33-1S-6E	3,196	3,158	McClosky limestone	240	11-4-41	4
South Lawrence, *Lawrence*	Evarts, Catt No. 1	SW SE SW 23-2N-12W	1,397	1,369	Buchanan sandstone	25	5-27-41	7
Walpole, *Hamilton*	Chevigny, Phillips No. 1	SW NW SW 26-6S-6E	3,193	3,053	Aux Vases sandstone	53	7-1-41	25
West Frankfort, *Franklin*	Adkins, Orient Coal Co. No. B-1	SE NE NW 12-7S-2E	2,080	2,040	Tar Springs sandstone	31	2-25-41	1
Xenia, *Clay*	Carter Oil Co., A. M. Keller	C W SW SW 4-2N-5E	2,806	2,786	Aux Vases sandstone	44	11-25-41	1

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[1] Biehl sandstone production in area since 1936.
[2] Gas, millions of cubic feet.

TABLE 3.—*Extensions to Pools in Illinois in* 1941

Pool, *County*	Company and Farm	Location	Total Depth, Ft.	Depth to Top, Ft.	Producing Formation	Initial Production, Bbl.	Date of Completion
Benton, *Franklin*	Morgan, Minier No. 1	NW NW NE 36-6S-2E	2,163	2,114	Tar Springs sandstone	912	4-22-41
Benton N., *Franklin*	Oil Carriers, Casper No. 1	SE SW NW 1-6S-2E	2,623	2,606	Paint Creek Stray sandstone	240	10-7-41
Bone Gap, *Edwards*	Tidewater, Provident Mutual No. 1	E NE SE 13-1S-10E	3,206	3,187	McClosky limestone	86	12-6-41
Bonpas W., *Richland*	Ohio Oil Co., Lambert No. 1	SE SE NW 17-2N-14W	3,149	3,124	McClosky limestone	90	10-28-41
Bonpas W., *Richland*	Ohio Oil Co., Hall No. 1	W NW NE 20-2N-14W	3,162	3,137	McClosky limestone	30	12-16-41
Boyleston, *Wayne*	Watkins & Weinert, Bright No. 1-B	N NE NE 2-2S-7E	3,334	3,313	McClosky limestone	440	9-3-41
Centerville E., *White*	Sun Oil Co., Straw No. 1	SE SE NW 7-4S-10E	2,551	2,477	Tar Springs sandstone	151	11-25-41
Clay City Cons.. *Clay, Wayne*	Sanders, Hubble No. 1	E ½ SW SE 30-2N-8E	3,038	3,013	McClosky limestone	1,360	4-29-41
Clay City Cons., *Clay, Wayne*	Pure Oil Co., Michels No. 1-A	W SW NW 25-2N-7E	3,065	3,039	McClosky limestone	7	5-13-41
Clay City Cons., *Clay, Wayne*	Rock Hill Oil Co., Doff No. 1	NW SW SW 20-3N-8E	2,899	2,674	Cypress and Bethel sandstone	107	9-23-41
Dix, *Jefferson*	L. & W., Sargent No. 1	SW SW NW 22-1S-2E	1,938	1,931	Bethel sandstone	63	5-27-41
Herald, *White*	Mabee Drilling Co., Knight No. 1	SW SW SE 10-7S-9E	2,266	2,256	Tar Springs sandstone	115	2-4-41
Hoodville, *Hamilton*	Texas Co., McDonald No. 1	NW NE SW 11-6S-6E	3,078	3,071	Aux Vases sandstone	106	6-24-41
Iola, *Clay*	Madden, Ging No. 1	SE SE NE 17-5N-5E	2,397	2,373	Aux Vases sandstone	100	4-22-41
Irvington, *Washington*	Powell, Holle No. 1	NW NW NE 15-1S-1W	1,527	1,519	Bethel sandstone	168	6-17-41
Irvington, *Washington*	Gulf, Maschoff No. 1	SE SE SW 10-1S-1W	1,531	1,522	Bethel sandstone	146	7-15-41
Johnsonville, *Wayne*	Olson Drill. Co., Porter No. 1	W NW SE 36-1N-6E	3,207	3,194	McClosky limestone	690	8-19-41
Johnsonville, *Wayne*	Pioneer Drill. Co., Williamson No. 1	SW NE 22-1N-6E	3,189	3,168	McClosky limestone	1,200	9-9-41
Mt. Carmel, *Wabash*	Olds, Riverside Park No. 1	NE SE SW 21-1S-12W	1,991	1,980	Cypress sandstone	180	5-20-41
Mt. Carmel, *Wabash*	Kennedy, Carson No. 1	SW SE NE 16-1S-12W	2,112	2,081	Bethel sandstone	30	7-1-41
Mason, *Effingham*	Lynch, Burk No. 1	SW SE NW 27-6N-5E	2,302	2,276	Bethel sandstone	175	6-10-41
Maunie S., *White*	Cherry & Kidd, Prell No. 1	NE SE SW 24-6S-10E	2,268	2,240	Tar Springs sandstone	147	6-3-41
Mill Shoals, *White, Hamilton*	Cherry & Kidd, Gardner No. 1	SE SE NE 24-3S-7E	3,252	3,228	Aux Vases sandstone	125	10-21-41
New Harmony S., *White*	Bell Bros., Morris No. 1	NW SW NW 21-5S-14W	2,373	2,348	Tar Springs sandstone	116	2-4-41
New Harmony Cons., *White*	Compton & Fotiades, Gray No. 1	NE SW SW 21-4S-14W	2,862	2,838	Aux Vases sandstone	800	6-24-41
New Harmony Cons.; *White*	First Nat. Petr. Trust, Johnson No. 1	NE SE NW 5-5S-14W	2,978	2,944	McClosky limestone	65	7-22-41
Noble, *Richland*	Davis, Schan No. 1	W SW NW 27-3N-9E	3,059	3,036	McClosky limestone	42	6-24-41
Noble, *Richland*	Pure Oil Co., Boley No. 1-A	E NW SE 28-4N-9E	3,003	2,991	McClosky limestone	550	12-30-41
North Boos, *Jasper*	Lain, Henry No. 1-A	SW NW NW 9-6N-10E	2,829	2,794	McClosky limestone	273	5-6-41
Parkersburg, *Edwards*	Central Pipe Line Co. and Kent, Stremms No. 1	E SE NE 31-2N-14W	3,123	3,116	McClosky limestone	1,167	10-28-41
Roland, *White*	Kingwood & Exchange, Porter No. 1	NE SW SW 12-7S-8E	2,660	2,573	Cypress sandstone	36	3-25-41
Roland, *White*	Fisher Oil Co., Ellis No. 1	NE SW SE 11-7S-8E	2,167	2,116	Waltersburg sandstone	308	6-3-41
Sailor Springs, *Clay*	Scott, Rodgers No. 1	NE NW NW 36-4N-7E	2,319	2,312	Tar Springs sandstone	20	10-7-41
Sailor Springs, *Clay*	W. C. McBride, Inc., Drake No. 1	SE SW NE 34-4N-7E	2,610	2,581	Cypress sandstone	48	8-26-41
Sailor Springs, *Clay*	Williams, Keck No. 1	NE NE SW 35-4N-7E	2,323	2,315	Tar Springs sandstone	57	9-23-41
Sims, *Wayne*	Swan-King, Spencer No. 1	W SE NE 28-1S-6E	3,219	3,169	McClosky limestone	210	12-16-41
Stokes, *White*	Pure Oil and Carter Oil Cos., Kisner No. 1	SE SE SE 7-6S-9E	2,856	2,800	Paint Creek sandstone	134	7-15-41
Walpole, *Hamilton*	The Texas Co., Shasteen No. 1	C E SE SW 27-6S-6E	3,080	3,064	Aux Vases sandstone	161	7-8-41
Woburn, *Bond*	A. J. Hausman, Durr No. A-2	NW NW NE 10-6N-2W	1,027	1,009	Bethel sandstone	13	10-21-41
Woodlawn, *Jefferson*	Kingwood, First Nat. Bank No. 1	SE NE SW 35-2S-1E	1,978	1,964	Bethel sandstone	961	7-22-41

TABLE 4.—*Completions and Production of Oil in Illinois Since Jan.* 1, 1936

Year	Number of Completions	Number of Producing Wells	Production, Thousands of Barrels		
			New Fields[a]	Old Fields[a,b]	Total[c]
1936	92	52			4,445
1937	449	292	2,884	4,542	7,426
1938	2,541	2,010	19,771	4,304	24,075
1939	3,675	2,970	90,908	4,004	94,912
1940	3,829	3,080	142,969	4,678	147,647
1941:					
Jan.	256	184	9,866	427	10,293
Feb.	199	140	8,698	371	9,069
Mar.	242	185	9,983	409	10,392
Apr.	259	191	9,861	435	10,296
May	352	267	10,054	445	10,499
June	303	227	9,973	432	10,405
July	328	245	10,427	427	10,854
Aug.	456	363	11,670	416	12,086
Sept.	472	391	12,257	435	12,692
Oct.	357	279	12,642	463	13,105
Nov.	352	271	11,694	422	12,116
Dec.	262	182	11,869	463	12,332
	3,838	2,925	128,994	5,145	134,139

[a] Production figures based on information furnished by oil companies and pipe-line companies.

[b] Includes Devonian production at Sandoval and Bartelso.

[c] From the U. S. Bureau of Mines.

In the Salem pool 99 producing wells were deepened from the Devonian limestone to the Kimmswick ("Trenton") limestone, which was productive in the field. The Devonian limestone was tested in the Louden pool and found productive, and during the year 59 Devonian wells were completed in the field. The St. Peter sandstone was tested in the Salem field and found nonproductive. No saturation was reported below the Kimmswick limestone. The St. Peter was also tested in the Louden pool and found nonproductive. A small part of the Kimmswick limestone showed oil saturation in the test drilled but the amount of saturation was not commercial.

PROSPECTS FOR 1942

The outlook for 1942 is for a greatly reduced drilling program in proven areas and for less exploration throughout the state. This decrease in activity is brought about by the difficulty of obtaining equipment for the wells and the introduction of the current well-spacing program.

ECONOMIC DATA

On the basis of posted prices, the total value of the oil produced in 1941 was approximately $174,380,700. The average price calculated from the available data on production and prices for the state was $1.30 per barrel for the year. Posted prices for Illinois crude oil in 1941 were as shown in Table 9.

TABLE 5.—*Wildcat Wells Drilled in Illinois in* 1941

Reason for Drilling	Total Number	Successful	Per Cent
Geology, geophysics and geochemistry	292	63	21.6
Not based on geologic, geophysical or geochemical information	173	0	0
Doubtful	101	21	20.8
Unknown	25	0	0
Total	591	84	14.2

In 1941, a total of 9,513,547 ft. of hole was drilled in the state. Of this amount 7,357,193 ft. was drilled in producing wells. With an assumed average cost of $3.00 per foot, the total investment in drilling was $28,540,641, including both producing wells and dry holes. The average depth of all wells drilled in the state in 1941 was 2480 ft., as compared with 2500 ft. in 1940.

The average initial daily production of the oil wells was 278 bbl., which was less than half of that for 1940. The large initial production of the Devonian wells in Salem and Centralia fields accounted for the high initial daily average of 573 bbl. for 1940.

PIPE LINES AND REFINERIES

Pipe-line construction in Illinois in 1941 was limited principally to the construction of lines connecting the new pools with trunk lines already constructed. Most of the construction was to provide outlets for the new pools in Franklin, Hamilton,

TABLE 6.—*Important Tests in* 1941

County	Pool or Wildcat	Location	Company and Farm	Total Depth, Ft.	Deepest Formation Tested	Top, Ft.	Remarks	Date Completed
Adams	Wildcat	12-2S-8W	Schachtsick, Reichart No. 1	901	St. Peter	820	Dry	5/20/41
Bond	Wildcat	28-4N-4W	Farrelly, Kyle No. 1	2,150	Devonian	2,115	Dry	5/6/41
Bond	Wildcat	21-6N-2W	Schwarz & Shell, Studebaker No. 1	3,206	"Trenton"	3,144	Dry	8/5/41
Bond	Wildcat	15-6N-2W	Texas, Mull No. 1	2,476	Devonian		Dry	7/15/41
Bond	Wildcat	1-4N-4W	Haines & Jackson, Hunter No. 1	2,539	Ste. Genevieve	2,420	Dry	3/4/41
Champaign	Wildcat	18-17N-11E	Union Products Petr. Co., Messman No. 1	1,850	"Trenton"	1,683	Dry	5/20/41
Champaign	Wildcat	18-22N-8E	Robinson, Springer No. 1	1,404	"Trenton"	1,255	Dry	10/28/41
Christian	Wildcat	24-12N-1W	Olson Drill. Co. Tex. No. 1	[2,720	Devonian	2,540]	Dry	6/10/41
Christian	Wildcat	26-15N-2W	Marlow et al., Howell No. 1	2,016	Devonian	1,915	Dry	7/29/41
Clark	Westfield	18-11N-14W	Harvey, Phillips No. 1	1,560	Dev.-Sil.		Dry	6/24/41
Clark	Wildcat	1-9N-14W	Swan-King, Claypool	1,687	Devonian	1,622	Dry	12/16/41
Clay	Clay City Cons.	4-2N-8E	Pure, Mosely, No. "B" 3	4,840	Devonian	4,669	Dry	10/21/41
Clinton	Bartelso	9-1N-3W	Mosebach, Schlarmann No. 1	4,213	St. Peter	4,175	Dry	4/22/41
Clinton	Wildcat	27-3N-1W	Obering et al., Yantis No. 1	2,871	Devonian	2,802	Dry	4/8/41
Clinton	Wildcat	22-1N-5W	Gerson et al., Billhart No. 1	3,217	"Trenton"	2,955	Dry	8/5/41
Coles	Wildcat	33-14N-10E	Allen & Sherritt, Taylor No. 1	1,143	Devonian		Dry	3/11/41
Coles	Wildcat	36-14N-10E	East Oakland Syndicate, Temple No. 1	2,290	"Plattin"	2,145	Dry	2/25/41
Crawford	Oblong	7-6N-13W	Powers, Kirtland No. 1	3,110	Devonian	3,095	Dry	5/13/41
Douglas	Wildcat	33-16N-9E	Illinois Mid-Continent, Bragg No. 1	700	Devonian		Dry	10/28/41
Dupage	Wildcat	2-40N-9E	I.C.R., Bartlett	1,175	Franconia		Dry	12/30/41
Edgar	Wildcat	19-15N-13W	Leonard, Baker No. 1	960	Devonian	890	Dry	9/30/41
Fayette	Louden	21-8N-3E	Carter Oil Co., Brauer No. 6-D	4,679	St. Peter	4,421	Dry	11/24/41
Fayette	Wildcat	13-4N-1W	Angelo-Twelve Oil Co., Oates No. 1	3,056	Devonian	2,942	Dry	1/14/41
Fayette	Louden	16-8N-3E	Whisenant, Lilley No. 25-D	3,131	Devonian	3,063	1,243 BOF	5/27/41
Fulton	Wildcat	11-7N-1E	Lee Twp. Oil Co., Walker No. 1	955	"Trenton"	953	Dry	5/13/41
Hancock	Wildcat	28-4N-5W	Tate, Rice No. 1	2,085	Dresbach		Dry	4/29/41
Jackson	Wildcat	9-8S-3W	Magnolia Petr. Co., Smith Heirs No. 1	3,893	"Trenton"	3,705	Dry	1/21/41
Johnson	Wildcat	24-11S-3E	Benedum & Trees Oil Co., Cavitt, No. 1	4,250	Devonian	4,097	Dry	3/11/41
Knox	Wildcat	10-10N-3E	Davis, Byland No. 1	1,200	"Trenton"	967	Dry	6/3/41
Lawrence	Wildcat	20-3N-12W	Robinson, Sauers No. 1	5,013	"Trenton"	4,862	Dry	2/25/41
McLean	Wildcat	28-22N-1E	Funks Grove Oil & Gas Co., Crawford No.1	2,115	"Trenton"	1,995	Dry	5/27/41
Macoupin	Wildcat	1-9N-7W	Bridges et al., Feiker No. 1	1,613	Devonian	1,505	Dry	4/1/41
Madison	Wildcat	27-5N-8W	Kiskadden, Fischer No. 1	1,955	Decorah	1,945(?)	Dry	11/4/41
Madison	Wildcat	22-3N-6W	Wickwire et al., Ellis No. 1	1,410	Devonian	1,363	Dry	2/11/41
Montgomery	Wildcat	28-9N-4W	Brown et al., Luddeke No. 1	2,008	Devonian	1,970	Dry	5/20/41
Montgomery	Wildcat	10-9N-2W	Hoover, Battles No. 1	2,598	Devonian	2,519	Dry	5/20/41
Montgomery	Wildcat	20-10N-2W	Detrick, Banes No. 1	2,528	Dev.-Sil.	2,298	Dry	7/1/41
Montgomery	Wildcat	3-10N-2W	Benedum & Trees, Janssen Heirs	3,237	"Trenton"	3,144	Dry	8/19/41
Montgomery	Wildcat	28-9N-4W	Brown & Hager, Luddeke No. 1	1,810	Devonian		Dry	2/18/41
Morgan	Wildcat	2-13N-10W	Hunt Cuddy No. 2	1,512	"Trenton"	1,380	Dry	4/15/41
Morgan	Wildcat	1-16N-11W	Measley et al., Crum No. 1	1,200	"Trenton"	1,120	Dry	4/15/41
Morgan	Wildcat	28-13N-8W	Magnolia Petr., Keplinger No. 1	1,765	"Trenton"	1,585	Dry	9/9/41
Moultrie	Wildcat	31-14N-4E	Olson Drill. Co., Ekiss No. 1	2,947	Dev.-Sil.	2,768	Dry	6/24/41
St. Clair	Wildcat	31-3S-6W	Alspach, Smith No. 1	1,715	Devonian	1,681	Dry	7/15/41
St. Clair	Wildcat	2-2S-9W	Magnolia Petr., Probst No. 1	1,450	"Trenton"		Dry	7/15/41
St. Clair	Wildcat	32-2N-7W	Morris, Rasp No. 1-A	2,075	"Trenton"	1,947	Dry	10/14/41
St. Clair	Wildcat	26-1N-9W	Gass and Frazier, Hahn No. 1	1,500	"Trenton"	1,469	Dry	11/25/41
Scott	Wildcat	27-13N-13W	Bedell, Adams No. 1	1,050	St. Peter	875	Dry	3/25/41
Shelby	Wildcat	12-13N-3E	Olson Drill. Co., Atkinson No. 1	2,922	Devonian	2,822	Dry	7/1/41
Shelby	Wildcat	36-13N-3E	O. C. Brunsbold, Harley-Yantis, No. 1	3,061	Devonian	2,970	Dry	2/4/41
Vermillion	Wildcat	30-18N-13W	Sylvestre, Trisler No. 1	1,775	Devonian	1,428	Dry	6/10/41
Warren	Wildcat	11-9N-1W	Monarch Oil Co., Hoadley No. 1	538	Dev.-Sil.		Dry	9/3/41
Washington	Wildcat	32-2S-4W	Bergundthal Dement No. 1	2,395	Devonian	2,347	Dry	11/25/41

Wabash, Wayne, and White Counties. Pipe-line construction in Illinois during 1941 was as follows:

Crude Oil

Ashland Oil and Transportation Co.—6 miles 4-in., Johnsonville field to Sims field, Wayne County.

Centralia Crude Oil Purchasing Co.—2½ miles 3-in. and 4-in., Tonti field to Salem field.

Central Pipe Line Co.—4 miles 4-in., Benton field to Benton North field; 2 miles 4-in., Parkersburg field to Illinois Pipe Line.

R. Hal Compton Crude Oil Purchasing Co.—13 miles 6-in., Worth Refining Company's refinery, Blue Island, Ill., south to the Texas-

TABLE 7.—*Summary of Drilling and Initial Production in Illinois for* 1941

County	Number of Wells Drilled in 1941			Total Initial Production		Number of Feet Drilled in 1941[a]	
	Completions	Producing		Oil, Bbl.	Gas, Millions Cu. Ft.	Total	Producing Wells
		Oil	Gas				
Adams	5	0	0	0	0	4,331	0
Bond	21	4	0	102	0	27,627	3,667
Bureau	2	0	0	0	0	3,126	0
Cass	1	0	0	0	0	501	0
Champaign	5	0	0	0	0	6,122	0
Christian	3	0	0	0	0	6,625	0
Clark	20	7	1	96	1.0	15,577	5,844
Clay	93	59	0	13,500	0	258,033	157,324
Clinton	64	25	1	1,090	17.5	97,385	37,886
Coles	8	1	0	30	0	10,609	1,842
Crawford	5	1	0	6	0	9,914	953
DeKalb	0	0	0	0	0	1,180[b]	0
Douglas	2	0	0	0	0	1,550	0
DuPage	1	0	0	0	0	1,175	0
Edgar	9	1	1	10	1.5	4,852	950
Edwards	52	36	0	24,082	0	143,894	95,562
Effingham	32	17	0	2,096	0	67,982	37,144
Fayette	238	190	0	28,076	0	476,575	388,525
Franklin	277	231	0	64,087	0	625,315	502,644
Fulton	2	0	0	0	0	1,960	0
Gallatin	96	62	0	8,167	0	198,257	124,577
Greene	1	0	0	0	0	570	0
Hamilton	432	372	0	115,356	0	1,369,026	1,168,414
Hancock	1	0	0	0	0	2,085	0
Henry	0	0	0	0	0	275[b]	0
Jackson	10	1	0	5	0	22,597	2,387
Jasper	176	140	0	55,077	0	494,998	393,857
Jefferson	184	147	0	51,353	0	368,856	263,748
Johnson	2	0	0	0	0	4,958	0
Knox	1	0	0	0	0	1,200	0
LaSalle	3	0	0	0	0	2,613	0
Lawrence	48	18	8	1,200	32.5	72,712	33,189
Logan	0	0	0	0	0	630[b]	0
McDonough	10	3	0	4	0	6,361	1,377
McLean	1	0	0	0	0	2,115	0
Macoupin	8	3	0	46	0	6,787	1,352
Madison	3	0	0	0	0	2,220	0
Marion	127	95	0	10,073	0	347,001	278,169
Monroe	3	3	0	50	0	1,415	1,415
Montgomery	15	1	0	22	0	18,739	602
Morgan	5	0	0	0	0	5,592	0
Moultrie	1	0	0	0	0	2,947	0
Perry	5	0	0	0	0	6,463	0
Pike	1	0	0	0	0	451	0
Pope	2	0	0	0	0	3,440	0
Randolph	7	0	0	0	0	6,934	0
Richland	99	68	0	31,283	0	293,288	198,154
St. Clair	38	27	0	2,441	0	28,488	18,552
Saline	13	2	0	92	0	36,759	6,142
Schuyler	1	0	0	0	0	735	0
Scott	1	0	0	0	0	1,050	0
Shelby	17	2	0	62	0	34,112	3,632
Vermilion	1	0	0	0	0	1,775	0
Wabash	356	285	1	35,271	1.6	662,371	510,013
Warren	1	0	0	0	0	538	0
Washington	69	43	0	3,658	0	101,968	64,519
Wayne	409	340	0	242,054	0	1,296,202	1,068,898
White	839	728	1	118,395	3.5	2,317,003	1,985,855
Whiteside	2	0	0	0	0	2,156	0
Williamson	10	0	0	0	0	23,527	0
	3,838	2,912	13	807,784	57.6	9,513,547	7,357,193

[a] Includes old wells deepened.
[b] Old well deepened.

Empire and Sinclair Pipe Line Company's trunk lines to East Chicago, Indiana.

Farm Bureau Oil Co.—5 miles 4-in., New Harmony Consolidated field to Indiana.

Gulf Pipe Line Co.—75 miles 10-in. loops in its trunk line across Illinois.

Illinois Pipe Line Co.—33 miles 8-in., Benton field to Enfield Station, White County; 8½ miles 8-in., Parkersburg field to Lancaster Station, Wabash County; 64 miles 10-in. loops in line from Enfield Station, White County, to Stoy Station, Crawford County.

Marimac Oil Co.—6 miles 5-in. and 7-in., Johnsonville field to loading rack at Cisne, Illinois.

Pure Transportation Co. (formerly Wabash Pipe Line Co.)—9 miles 4-in., New Harmony Consolidated field to Enfield Station, White County; 6 miles 6-in., Johnsonville field to Cisne field; 5 miles 6-in., West Clay City field to Cisne-Clay City line; 2 miles 4-in., Ste. Marie field to trunk line of Sohio Pipe Line Company.

Sohio Corporation.—33 miles 6-in., Benton field to Enfield Station, White County; 12½ miles 4-in., Dahlgren field to Hoodville Station, Hoodville field; 8½ miles 6-in., Salem field to Dix-Centralia line; 4½ miles 4-in., New Harmony Consolidated field to Indiana; 9½ miles 4-in., Omaha field to Storms field; 6-in. loop in line from Storms field to Indiana; 12 miles 4-in., Woodlawn field to Dix-Centralia line; 3½ miles 4-in., Burnt Prairie field to Enfield Station, White County; 9 miles 4-in. and 6-in., Albion field to Indiana; 16 miles 4-in., Mt. Carmel field to Lancaster Station, Wabash County; 7½ miles 3-in., Keensburg Consolidated field to Mt. Carmel field; 5.5 miles 4-in., Mill Shoals field to Boyleston-Barnhill line; 4 miles 4-in., Sailor Springs field to trunk line near Clay City, Ill.; 14 miles 4-in., Inman field to Indiana; 10 miles 4-in., and 8 miles 6-in. loop, Johnsonville field to Flora Station, Clay County.

Sun Pipe Line Co.—1½ miles 4-in., Rural Hill field to Benton-Enfield trunk line of the

TABLE 8.—*Fields with Wells Producing from More than One Formation*

Field	County	Total Number of Combination Wells	Number of Wells and Producing Formations[a]
Clay City Consolidated	Clay, Wayne	8	1CB, 2AR, 5RM
Albion	Edwards	6	3BA, 1BM, 2BAM
Louden	Fayette, Effingham	187	101CP, 43CB, 14PB, 29CPB
Dale	Hamilton	9	1CB, 7BA, 1RM
Hoodville	Hamilton	33	33BA
Rural Hill	Hamilton	32	13AL, 5ALM, 6LM, 8AM
Salem	Marion	706	471BA, 231MS, 2BAM, 1AM, 1MD
Dundas Consolidated	Richland, Jasper	2	1AM, 1RM
Keensburg Consolidated	Wabash	8	2BiC, 3CB, 2BA, 1AM
Mt. Carmel	Wabash	10	2BiC, 2BiCM, 6CM
Irvington	Washington	1	1CB
Barnhill	Wayne	2	2RM
Boyleston	Wayne	1	1RM
Johnsonville	Wayne	2	2AM
Iron	White	3	1TC, 1TH, 1BM
New Harmony Consolidated	White	160	5CP, 1TPB, 30PB, 1TB, 7CBM, 7WCBA, 3CBAM, 1TCM, 2WC, 27CB, 28CBA, 2WA, 3TCA, 3TA, 1TCB, 4AM, 8BA, 1WB, 1TM, 1CM, 2WCBAM, 1WCB, 1CPM, 11CA, 2TC, 1CPB, 1BM, 1CPBAM, 1BiCA, 1PA, 1WM, 1WBM, 1RM
Roland	White	24	1WCA, 3CB, 7WB, 9WA, 1CBA, 1CA, 1WP, 1WCP
Mill Shoals	White, Hamilton	2	2AM
		1,196	

[a] Names of sands indicated, as follows:

Bi, Biehl
W, Waltersburg
T, Tar Springs
H, Hardinsburg
C, Cypress
P, Paint Creek Stray
B, Bethel
A, Aux Vases
R, Rosiclare
M, McClosky
S, Salem
D, Devonian

Illinois Pipe Line Co.; looped 4-in. line New Harmony Consolidated field to Centerville station.

Texas Pipe Line Co.—21 miles 6-in., Salem field to Woodlawn field; 5 miles 6-in., Johnsonville field to their Aden-Clay City line; 18 miles 6-in., Johnsonville field to Clay City station; 15 miles of proposed 6-in. line from Johnsonville field to Rural Hill field.

Toronto Pipe Line Co.—9 miles 6-in., Albion station to Griffin field, Ind.; 5 miles 4-in., New Harmony Consolidated to Griffin field, Indiana.

Western Pipe Line Co.—1½ miles 4-in., Centerville East field to Centerville station.

Natural Gas

Five Partners Gas Co.—2 miles 6-in., Albion field to Albion, Illinois.

Illinois Iowa Power Co.—8 miles 3-in., Midland City to Clinton, Ill.; 20 miles 3-in., Annawan to Galva, Illinois.

Illinois Natural Gas Co.—47 miles 8-in., Peoria to Galesburg, Ill.; 10 miles 4-in., Knoxville to Abingdon, Ill.; 14 miles 3-in., Lincoln to Midland City, Ill.; 6 miles 2-in., Atwood to Arthur, Illinois.

Kentucky Natural Gas Corporation.—14 miles 4-in., Indiana to Robinson, Ill.; 9 miles 2-in., Robinson to Oblong, Illinois.

Mississippi River Fuel Corporation.—10 miles 12-in. loop in line from Venice to Wood River, Illinois.

Natural Gas Pipeline Company of America.—127 miles 20-in., Geneseo station, Henry County to Wisconsin state boundary line.

Panhandle Eastern Pipe Line Co.—87 miles 24-in., loops in trunk line across Illinois.

No new refineries were constructed in Illinois during 1941, but the total refinery capacity was increased from 258,750 to 275,450 bbl.

TABLE 9.—*Posted Prices for Illinois Crude in* 1941

Field	Period Beginning					
	Aug. 21, 1940	Apr. 1, 1941	Apr. 10, 1941	Apr. 28, 1941	May 21, 1941	Dec. 31, 1941
Old fields.....	$1.00	$1.05	$1.07	$1.12	$1.22	$1.22
Central basin fields, Salem area and Griffin area.	1.15	1.20	1.22	1.27	1.37	1.37

During the year, 64.7 per cent of Illinois crude-oil production was sent to refineries in the Central refining district (Illinois, Indiana, Kentucky, Michigan, and western Ohio), 18.0 per cent to the Appalachian refining district (eastern Ohio, western New York, western Pennsylvania, and West Virginia), and 7.4 per cent to the Atlantic seaboard. For December 1941 the runs to stills in the Central and Appalachian refining districts were 26,653,000 bbl. Of this amount, Illinois production was 46.3 per cent. Stocks of crude petroleum on hand in Illinois on Dec. 31, 1941, were 18,280,000 bbl. as compared with 13,944,000 bbl. on Dec. 31, 1940. Stocks of refined products in the Central and Appalachian refining districts compared with the previous year are as follows:

Product	Dec. 31, 1941, Bbl.	Dec. 31, 1940, Bbl.
Gasoline..................	22,011,000	19,305,000
Gas oil and distillate fuel....	4,763,000	3,629,000
Residual fuel oil............	4,479,000	3,221,000

PRODUCTION OF NATURAL GAS

The amount of natural gas produced and marketed in Illinois during 1941 was 1,699,400,000 cu. ft. The amount marketed from each field is given in Table 10.

Eight new wells were drilled and one well was abandoned within proved territory in the Russellville gas field during 1941, bringing the total number of producing wells in the field to 48. The productive area of the Buchanan sand proved by drilling is 1600 acres, 20 acres more than in 1940. Six wells were completed in the Bridgeport sand at an average depth of 793 ft., and the top of the sand was encountered at an average depth of 760 ft. The initial production of the wells was of the order of 2,000,000 cu. ft. each. The productive area of the Bridgeport sand proved by drilling is 260 acres. There was no new development in the Ayers gas field, Bond County, during the year, and no wells were abandoned.

Natural gas production in the Louden pool for 1941 is estimated to be 13.7 billion cu. ft. The average daily production at the end of the year was approximately 36,000,000 cu. ft. Approximately 15,000,000 cu. ft. of gas is processed daily by Carter Oil Company's two repressuring plants, and 6,000,000 cu. ft. of residue gas is injected into the producing sands. Residue gas from the two plants is furnished also to the G. H. & G. Pipe Line Co. for the towns of St. Elmo and Brownstown, Ill., at the rate of 1,400,000 cu. ft. daily. The pipeline company also receives 61,600 cu. ft. of gas daily from a well in the Louden field, which is producing from a basal Pennsylvanian sandstone.

The production of natural gas in the Salem field for 1941 is estimated to be 35.4 billion cu. ft. At the end of the year the estimated daily production was 82,000,000 cu. ft. Of this amount 59,000,000 cu. ft. daily is processed by the natural-gasoline plants in the field. The Texas Company processes 30,000,000 cu. ft. daily; the Warren Petroleum Co., 16,000,000 and the Sunflower Natural Gasoline Co., 13,000,000 in its two plants. The Texas Company returns 4,000,000 cu. ft. of residue gas daily to the producing sands in its repressuring operation.

Residue gas from the Warren Petroleum Company's plant is supplied to Salem, Centralia and Mt. Vernon, Ill. This consumption at the end of the year was approximately 1,000,000 cu. ft. daily. Centralia and Mt. Vernon began using the gas about Nov. 15, 1941.

The Centralia field produced an estimated 1.8 billion cu. ft. of gas during 1941. The decline in Devonian oil production in the field largely accounts for the decline in gas production during the past year. Daily average production of natural gas at the end of 1941 was estimated to be 4,000,000 cu. ft. Repressuring of the Cypress and Bethel sandstones has been carried on by two companies operating in the field. One of the two repressuring projects was shut down at the end of the year. A total of 180,000 cu. ft. of gas daily was injected in the producing formations when both were in operation.

Production of natural gas in the Storms field continued to decline in 1941. Daily average production at the end of the year was estimated to be 5,000,000 cu. ft. Production of natural gas for 1941 is estimated to be 2.2 billion cubic feet. Repressuring of the producing sand was begun by one of the companies operating in the field. A total of 120,000 cu. ft. of gas daily is being injected through one input well.

The Warren Petroleum Co. has started construction of a natural gasoline plant in the New Harmony Consolidated field, White County. The company proposes to take 20,000,000 cu. ft. of gas daily from the New Harmony Consolidated, Griffin (Indiana) and Keensburg Consolidated fields. The residue gas is to be returned to the producing sands through certain wells that now are producing oil. The daily natural-gas production in these three fields is estimated to be 25,000,000 cu. ft. Gas production during 1941 is estimated to have been 9 billion cubic feet.

Natural gas produced with the oil in the Albion pool, Edwards County, was marketed to brick-manufacturing plants at Albion, Ill., during part of 1941. Daily average production for the field at the end of 1941 was approximately 1,000,000 cu. ft. Production for the entire year is estimated to have been 445,000,000 cubic feet.

New fields and further extension of the productive acreage in older fields in the Central Basin area increased the production of natural gas in that area during 1941. This area includes 33,800 productive acres in Jasper, Richland, Clay, Wayne, northern Hamilton and northwestern White counties. The total production is estimated to have been 24.5 billion cu. ft. The new Johnsonville field, in Wayne County, accounts for more than one third of the natural gas produced from the entire area. The fields on the south and southwest margin of the Illinois Basin in southern Illinois produced an estimated total of 14.5 billion cu. ft. of gas in 1941. These include among others the more important gas-producing fields, such as Woodlawn, Jefferson County; Benton, Franklin County; Rural Hill, Hoodville, and Dale, Hamilton County.

TABLE 10.—*Natural Gas in Illinois in* 1941

Field	County	Where Marketed	Amount Produced and Marketed, Cu. Ft.
Russellville gas	Lawrence	Lawrenceville, Bridgeport, Sumner and Olney, Ill. and Ind.	863,000,000
Ayers gas	Bond	Greenville, Ill.	13,400,000
Salem[a]	Marion	Salem, Centralia, and Mt. Vernon, Ill.	165,000,000
Louden[a]	Fayette	St. Elmo and Brownstown, Ill.	536,000,000
Albion[b]	Edwards	Albion, Ill.	122,000,000
Total Illinois			1,699,400,000

[a] Residue gas from natural gasoline plants.
[b] Used in brick plants only.

NATURAL GASOLINE, BUTANE AND PROPANE

Natural gasoline is produced at 44 plants in the old southeastern field, with a total output of approximately 11,000 gal. daily; two plants in the Louden field, with a daily output of 40,000 gal., four plants in the Salem field, with an output of 113,000 gal. daily. According to the U. S. Bureau of Mines,[*] Illinois produced 55,077,000 gal. of natural gasoline in 1941. In January, the amount was 3,372,000 gal.; there was a steady increase to 6,209,000 gal. in December. More than 75,000,000 cu. ft. of gas produced with the oil in the Illinois fields is processed daily in natural gasoline plants. Construction of a natural gasoline plant by the Warren Petroleum Co. has begun in the New Harmony Consolidated field, White County, and the construction of a plant in the Hoodville field, Hamilton County, is planned by the Texas Company.

Butane production in the Louden field plants is approximately 19,000 gal. daily, and in the Salem field 77,500 gal. daily. The production of propane is 13,000 gal. daily at Louden, and 34,400 gal. daily at Salem.

SECONDARY RECOVERY

Repressuring was continued of the Bethel and Aux Vases sandstones of the Chester series and the McClosky limestone of the lower Mississippian system in the Salem field. At the end of 1941 about 4,000,000 cu. ft. of "dry" gas was being injected daily into 53 gas-input wells; 85 sand faces are open in the 53 wells. Twenty-one new input wells were drilled in 1941.

Twenty gas-input wells were drilled in 1941 by the Carter Oil Co. for its repressuring project in the Louden field. This brought the total to 83 input wells in the field as of the end of the year, injecting approximately 6,000,000 cu. ft. of "dry" gas daily into the Cypress, Paint Creek Stray and Bethel sandstones of the Chester series.

Repressuring the Cypress and Bethel sandstones in the Centralia field has been carried on by two of the operating companies in the field. Approximately 80,000 cu. ft. is injected daily into the Cypress sandstone through one input well and 100,000 cu. ft. daily into the Bethel sandstone through three input wells. The repressuring project for the Bethel sandstone was temporarily shut down at the end of the year. Gas is injected in the Waltersburg sandstone in the Storms field, through one of the former producing wells.

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[*] G. R. Hopkins, personal communication February 1942.

Little change took place in 1941 in the repressuring or water-flooding operations in the old fields. Ten new air and/or gas-input wells were added in Crawford County and six were abandoned. Twenty-five air-input wells were abandoned in the Carlyle pool when the properties involved in the repressuring project were sold.

LEGISLATION

An Act amending the general mining law of Illinois, which included the regulation of drilling wells in Illinois, was approved and in force July 15, 1941. The new law provides that permits to drill shall be issued by the Department of Mines and Minerals, Springfield, Ill., which also regulates spacing and plugging of wells, disposal of brine, repressuring, and other operations. Federal Conservation Order M68, restricting drilling to one well to 40 acres, in order to save steel, was issued Dec. 23, 1941, and has led to a considerable reduction of drilling in the state during the first three months of 1942.

ACKNOWLEDGMENTS

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Oil and Gas Activity in Indiana in 1941

By Ralph E. Esarey* and Robert G. Reno*

Drilling activity and prospecting for oil and gas increased in Indiana in 1941 over the previous year. The greater part of the drilling and development continued to centralize in the Indiana portion of the Interior Coal Basin, in the southwestern part of the state, but other parts of the state were not neglected. Many wildcat wells were drilled, including a series of core tests through the mantle of drift on the southern flank of the Michigan Basin. These core tests have been followed by several unsuccessful production tests. Production tests were made also along the axis of the Logansport-Kankakee branch of the Cincinnati Arch.

In all, 411 field locations and 141 wildcat wells were completed in Indiana during 1941; that is, a total of 552 wells, an increase of 32 wells over the previous year. The field tests resulted in 260 oil wells, 57 gas wells, and 94 dry holes; wildcats included 16 oil wells, 3 gas wells and 122 dry holes. At the end of the year, 53 field wells and 34 wildcats were drilling. Gibson and Posey Counties led the state, with 154 and 155 wells drilled, respectively. However, 125 wells produced oil in Gibson County, while 98 produced oil in Posey County. Twenty-five per cent of all wells drilled were wildcat; 11 per cent of these produced oil and 5 per cent produced gas.

Griffin field continued to lead in drilling activity, with 157 successful wells and 20 dry holes (including important wells defining the field). Production is found in five pay zones (Tar Springs, Waltersburg, Elwren, Aux Vases and McClosky). It produced a major part of Indiana's estimated 7,200,000 bbl. of oil during the year. Heusler field, Posey County, expanded with 11 oil wells and 4 dry holes in the Waltersburg and Tar Springs. Vienna field, Posey County, completed four oil producers in the Mansfield sandstone, between 1200 and 1250 ft. The College field, discovered late in 1940, received three oil producers and two dry holes in the Aux Vases.

Two new fields were discovered in Posey County during the year: Lamott pool, in the Tar Springs, at 1950 ft., had initial production of 55 bbl. on discovery. One producer and one dry hole have been drilled since. Mt. Vernon pool found saturation in both the Waltersburg and Cypress formations. The discovery well tested about 1000 bbl. per day; it tested the McClosky at 2764 ft. Seven producers have been drilled since the October discovery. Welborne-Switch pool found oil in the Cypress sand at approximately 2500 ft., with an initial production of 33 bbl. One more well in the area proved a dry hole.

Gibson County had the following discoveries in 1941: The Patoka field was opened by a McClosky producer of 300 bbl. Another producing well has been drilled. An attempt was made to extend the Illinois Mt. Carmel field into Gibson County, Ind., and one producer of 24 bbl. was completed on the Indiana side. A dry hole has since been drilled, one location south. One small well was completed in the Mansfield at 1105 ft. in sec. 31, T.2 S., R.12 W., Gibson County promising a new field

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TABLE 1.—*Oil and Gas Production in Indiana*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
1	Alford, *Pike*	1919	240	960	3*xx*,*xxx*	3,500
2	Blairsville, *Posey-Vanderburgh*	1933	350	0	433,*xxx*	34,*xxx*
3	Bristow, *Perry*	1929	180	120	79,*xxx*	1,254
4	Bufkin-Caborn, *Posey*	1940	600	80	182,*xxx*	177,*xxx*
5	Cannelburg, *Daviess*	1925	6*xx*	5*x*	*y*	32,760
6	College, *Posey*	1940	80	0	49,*xxx*	35,822
7	Francisco, *Gibson*	1929	950	200	182,*xxx*	44,637
8	Glendale-Hudsonville, *Daviess-Pike*	1929	0	1,2*xx*	0	0
9	Greensburg, *Decatur*	1893	0	37,000	0	0
10	Griffin, *Gibson-Posey*[1]	1938	3,800	0	9,500,000	5,217,162
11	Harmon, *Pike*	1928	20	6*xx*	0	0
12	Hatfield, *Spencer*	1941	80	0	20,*xxx*	20,*xxx*
13	Hazleton, *Gibson*	1941	200	0	14,600	14,600
14	Harrison, *Harrison*	1910	0	6,6*xx*	0	0
15	Heusler, *Posey*	1938	250	0	646,*xxx*	202,329
16	Loogootee, *Martin-Daviess*	1900	3*xx*	1,9*xx*	*y*	0
17	Monroe City, *Knox*	1922	4*xx*	0	*y*	900
18	Mt. Vernon, *Posey*	1941	200	0	61,043	61,043
19	New Harmony, *Posey*[1]	1939	300	0	1,151,*xxx*	643,745
20	Oakland City, *Pike-Gibson*	1907	3,1*xx*	2*xx*	*y*	1,875
21	Oaktown, *Knox*	1930	40	1,000	60,*xxx*	2,*xxx*
22	Oatsville-Wheeling, *Pike-Gibson*	1919	1,9*xx*	0	*y*	125,*xxx*
23	Patoka, *Gibson*	1941	40	0	1,400	1,400
24	Prairie Creek, *Vigo*	1937	600	0	501,100	88,231
25	Riley, *Vigo*	1906	640	0	1*xx*,*xxx*	1,215
26	Rock Hill-Grandview, *Spencer*	1928	160	0	65,*xxx*	6,370
27	Rockport, *Spencer*	1939	125	1,400	50,871	27,447
28	Shelburn-Grayville, *Sullivan*	1911	5,0*xx*	1,6*xx*	7,1*xx*,*xxx*	65,857
29	Siosi, *Sullivan-Vigo*	1926	750	0	3,*xxx*,*xxx*	146,027
30	St. Thomas, *Knox*	1940	80	*x*	56,313	27,563
31	St. Wendells, *Posey*	1934	240	0	250,554	35,883
32	Trenton, *Many*	1886	127,*xxx*	650,*xxx*	107,*xxx*,*xxx*	14,640
33	Tri-County-Somerville, *Pike-Gibson*	1925	350	80	170,*xxx*	8,942
34	Troy-Tell City, *Perry-Spencer*	1928	850	80	120,1*xx*	15,695
35	Union-Bowman, *Pike-Gibson*	1916	4,6*xx*	5*xx*	*y*	175,6*xx*
36	Unionville, *Monroe*	1929	0	1,4*xx*	0	0
37	Vanderburgh, *Vanderburgh*	1931	580	0	434,*xxx*	33,156
38	Veale, *Daviess*	1926	400	0	*y*	9,360
39	West Princeton, *Gibson*	1903	1,6*xx*	5*xx*	1,3*xx*,*xxx*	4,300
40	Miscellaneous, *Several Counties*	1941	1*xx*	0	*y*	16,198
41	Total					7,295,515

[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Extends into Illinois.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
				During 1941		End of 1941			Number of Wells						
	To End 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
1	*y*	6*x*	97	1	1	0	7	21	0	7	*y*	35		38	
2	0	0	103	5	1	0	34	0	0	34				29	
3	*y*	0	45	0	15	0	4	0	0	4				33	
4	*y*	*y*	34	28	0	0	43	1	0	43				*y*	
5	*y*	0	76	14	7	0	24	0	0	24				*y*	
6	0	0	6	5	2	0	4	0	0	4				*y*	
7	1,248.2	4.5	46	4	2	1	28	1	0	28	690	*y*		26–38.6	
8	*y*	31.0	66	12	3	0	0	21	0	0	275	*y*			
9	4,3*xx*.0	177.9	39*x*	12	0	0	0	165	0	0	275	100			
10	0	0	400	157	12	1	386	0	1*x*	38*x*				37–39	
11	*y*	1*x*	28	0	0	0	0	4	0	0	450	25			
12	0	0	10	10	2	0	8	0	0	6					
13	0	0	3	3	0	0	3	0	1	2				*y*	
14	3,8*xx*	100	129	9	23	0	0	26	0	0	175	100			
15	0	0	49	19	2	0	41	0	0	41				37	
16	*y*	5.*x*	59	1	0	0	0	7	0	0	250	60			
17	0	0	15	0	0	0	7	0	0	7				*y*	
18	0	0	7	7	0	0	7	0	0	7	*y*	*y*		*y*	
19	0	0	26	0	0	0	26	0	0	26				39	
20	0	0	267	4	0	0	35	0	0	35				28	
21	1,903.5	96.6	80	2	11	0	5	25	0	5	281	107		35	
22	0	0	255	2	5	0	185	0	0	185				32	
23	0	0	2	2	0	0	2	0	0	2	*y*	*y*		*y*	
24	0	0	20	0	0	0	15	0	0	15				40	
25	0	0	33	0	0	0	1	0	0	1				50	
26	0	0	19	2	0	0	16	0	0	16				34	
27	855.47	461.*x*	63	8	0	0	15	33	0	15	390	248		36.7	
28	1,*xxx*	33.9	1,099	2	5	0	342	18	0	342	110	30		35	
29	0	0	85	2	3	0	49	0	0	49				46	
30	0	0	5	1	0	0	5	0	0	5				*y*	
31	0	0	28	2	1	0	26	0	0	26	*y*	*y*		*y*	
32	800,*xxx*	2*xx*	26,6*xx*	24	82	0	1*xx*	2*xx*	0	1*xx*	325	*y*		36	
33	*y*	*y*	74	0	0	0	14	*y*	0	14	*y*	*y*		34	
34	395.*x*	1.52	82	7	0	0	30	2	0	30	*y*	29		34	
35	*y*	*y*	403	4	9	0	279	*y*	0	279	*y*	*y*		34–36	
36	115.6	115.6	18	1	0	4	0	14	0	0	250	107			
37	0	0	95	3	2	0	56	0	0	56				30.5	
38	0	0	79	6	3	0	29	0	0	29				*y*	
39	*y*	0	151	1	7	0	31	0	0	31				*y*	
40	0	0	8	8	0	0	8	0	0	8					
41		1,355.44													

TABLE 1.—(*Continued*)

	Producing Formation								Deepest Zone Tested to End of 1941	
					Depth, Avg. Ft.					
Line Number	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	Oakland City and Brown sands	MisU	S	Por	630 1,080 1,130	640 1,100 1,140	10	A	St. Louis	1,413
2	Mansfield	PenL	S	Por	1,007	1,031	30	ML	Chester	1,920
3	Tar Springs, Cypress, Elwren	MisU	S	Por	280 460	320 520	20	ML	Ste. Genevieve	710
4	Pen(1–2), Mansfield, Cypress	Pen M(1–2) PenL, MisU	S	Por	340–1,130 633–2,370	368 739 1,179 2,401	12	A	Ste. Genevieve	2,865
5	L. Chester	MisU	S	Por	630	640	*y*	A	Chester	895
6	Aux Vases	MisU	S	Por	2,565	2,584	10	*y*	Ste. Genevieve	2,687
7	Brown, McCloskey	MisU MisM	S, OL, L	Por	1,340 1,600	1,380 1,650	25	A	Ordovician	4,006
8	Barker	MisU	S	Por	650	660	10	T	St. Louis	1,575
9	Trenton	OrdM	L	Por	886	907	10	A	Pre-Cambrian	3,055
10	Tar Springs, Waltersburg, Elwren, Aux Vases, McClosky	MisU (1,2,3,4) MisM	S OL	Por	2,150	2,900	*y*	AF	Salem	3,185
11	Mooretown	MisU	S	Por	1,100	1,125	15	A	Ste. Genevieve	1,321
12	Waltersburg	MisU	S	Por	1,029	1,044	*y*	*y*	St. Louis	1,783
13	McClosky, Salem	MisM	OL	Por	1,735 2,085	1,750 2,130	*y*	*y*	Silurian	3,450
14	New Albany	DevU	H	Fis	650	680	20	M	Trenton	1,770
15	Waltersburg, Tar Springs	MisU	S	Por	1,750 1,855	1,800 1,920	25	AF	Ste. Genevieve	2,643
16	Mooretown	MisU	S	Por	532	540	10	A	Trenton	3,025
17	Mansfield, Cypress, Mooretown, Paoli	PenL(1) MisU(2,3,4)	S, L	Por	1,225 1,475 1,560	1,240 1,560	*y*	M	Salem	1,935
18	Waltersburg, Cypress	MisU	S	Por	2,000 2,425	2,050 2,470	*y*	*y*	St. Louis	3,000
19	Waltersburg, McClosky	MisU MisM	S OL	Por	2,150	2,900	31	A	St. Louis	3,028
20	Oakland City, Brown	MisU	S	Por	1,085 1,107	1,112 1,126	10	A	Paoli	1,444
21	Staunton	PenL	S	Por	580 790	610 802	*y*	ML	Ste. Genevieve	1,592
22	Sample, Cypress, Mooretown, Paoli	MisU	S(1,2,3) L(4)	Por	1,250 1,270 1,340 1,725	1,270 1,290 1,360 1,740	*y*	A	Harrodsburg	2,050
23	McClosky	MisM	OL	Por	2,250	2,270	*y*	*y*	Ste. Genevieve	2,300
24	Corniferous Niagara	DevM SilM	L	Por	2,074	2,165	*y*	D	Silurian	2,232
25	Corniferous	DevM	L	Por	1,600	1,700	*y*	A	Niagaran	1,802
26	Sample	MisU	S	Por	1,310	1,320	10	MC	Ste. Genevieve	1,500
27	Penn, Palestine	PenL MisU	S	Por	885	905	10	A	St. Louis	1,707
28	Penn (1,2,3,4), Harrodsburg, Niagara	PenL(1,2,3,4) MisM SilM	(S1,2,3,4) L	Por	298–595 640–730 800–1,400 2,270	325–560 667–775 810–1,500 2,285	*y*	AM	Silurian	2,870
29	Corniferous, Niagara	DevM, SilM	L	Por	2,100	2,115	*y*	D	Trenton	3,554
30	McClosky	MisM	OL	Por	1,871	1,922	8	*y*	Ste. Genevieve	2,050
31	Mansfield	PenL	S	Por	1,007	1,031	30	ML	Chester	1,920
32	Trenton	Ord	L,D	Por-Fis	900	1,250	*y*	A	Pre-Cambrian	3,996
33	Brazil, Oakland City	PenL MisU	S	Por	315 1,317	331 1,335	10	A	Ste. Genevieve	1,998
34	Sample, Cypress, Mooretown	MisU	S	Por	468 714 747 805	492 728 759 827	*y*	NMF	Mis. Lime	1,708
35	Cypress, Mooretown, Paoli	MisU	S(1,2) L(3)	Por	945 1,233	950 1,250	*y*	A	Salem	2,205
36	Corniferous	DevM	L	Por	800	850	40	AF	Trenton	2,102
37	Mansfield	PenL	S	Por	899	911	*y*	ML	Ste. Genevieve	2,435
38	McClosky	MisM	OL	Por	1,161	1,169	10	A	Devonian	2,618
39	West Princeton	PenL	S	Por	890	920	*y*	A	St. Louis	3,905
40										
41										

TABLE 2.—*Summary of Drilling Operations in Indiana*

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Crawford	22	1 S	2 E	1,350	Mississippian	Devonian	J. C. Barnett			Dry hole
2	Daviess	15	1 N	5 W	3,250	Pennsylvanian	Trenton	Newton Pipe Line Co. et al.			Dry hole
3	Daviess	35	2 N	5 W	2,089	Pennsylvanian	Silurian	Newton Pipe Line Co.			Dry hole
4	Daviess	35	2 N	5 W	505	Pennsylvanian	M. Chester	P. L. Norris et al.			Dry hole
5	Daviess	35	2 N	5 W	528	Pennsylvanian	M. Chester	P. L. Norris et al.			Dry hole
6	DuBois	14	3 S	3 W	547	Mississippian	L. Mississippian	J. C. Howes & Son			Dry hole
7	Elkhart	11	38 N	4 E	?	Mississippian	Devonian	Headley, Poyser, McClure, Hendrix			Dry hole
8	Elkhart	13	38 N	4 E	2,021	Mississippian	Trenton	McPletcher			Dry hole
9	Elkhart	30	37 N	7 E	599	Mississippian	Devonian	John McLean			Dry hole
10	Elkhart	11	38 N	4 E	654	Mississippian	Devonian	A. W. Downs			Dry hole
11	Elkhart	11	38 N	4 E	655	Mississippian	Devonian	A. W. Downs			Dry hole
12	Elkhart	11	38 N	4 E	651	Mississippian	Devonian	A. W. Downs	47		Oil well
13	Elkhart	13	38 N	4 E	627	Mississippian	Devonian	R. B. Tamblyn			Dry hole
14	Elkhart	14	38 N	4 E	654	Mississippian	Devonian	J. C. Hudson			Dry hole
15	Elkhart	15	38 N	4 E	653	Mississippian	Devonian	Hostetter & Hynes			Dry hole
16	Elkhart	25	38 N	4 E	559	Mississippian	Devonian	Petroleum Exploration Co.			Dry hole
17	Gibson	36	1 S	10 W	1,338	Pennsylvanian	L. Chester	R. D. Brown, Inc.			Dry hole
18	Gibson	Fr 20	1 N	10 W	1,887	Pennsylvanian	St. Louis	McGinnis & Bitter	19		Oil well, N. Francisco
19	Gibson	24	1 N	10 W	1,703	Pennsylvanian	McClosky	R. N. Sylvestre			Dry hole
20	Gibson	26	1 N	10 W	1,832	Pennsylvanian	St. Louis	Kingwood Oil Co.	240		Discovery Hazleton
21	Gibson	36	1 S	10 W	1,340	Pennsylvanian	L. Chester	R. D. Brown, Inc.	90		Extension Hazlett
22	Gibson	21	1 S	12 W	1,988	Pennsylvanian	M. Chester	Princeton Mining Co.	24		N. Francisco gas field
23	Gibson	21	1 S	12 W	2,355	Pennsylvanian	St. Louis	Princeton Mining Co.	24		Mt. Carmel extension
24	Gibson	26	1 S	12 W	2,414	Pennsylvanian	Ste. Genevieve	Yingling & Hays			Dry hole
25	Gibson	5	2 S	10 W	2,045	Pennsylvanian	Ste. Genevieve	E. O. Olds et al.			Dry hole
26	Gibson	8	2 S	12 W	2,580	Pennsylvanian	Ste. Genevieve	Ward A. Wickwire			Dry hole
27	Gibson	10	2 S	12 W	2,462	Pennsylvanian	St. Louis	R. D. Brown, Inc.			Dry hole
28	Gibson	29	2 S	12 W	2,738	Pennsylvanian	St. Louis	R. D. Brown, Inc.			Dry hole
29	Gibson	31	2 S	12 W	1,112	Pennsylvanian	L. Penn	Bert Fields			Dry hole
30	Gibson	10	3 S	9 W	1,607	Pennsylvanian	M. Chester	Gulf Refining Co.			Dry hole
31	Gibson	13	3 S	9 W	1,058	Pennsylvanian	L. Chester	Magnolia			Dry hole
32	Gibson	14	4 S	10 W	2,140	Pennsylvanian	Ste. Genevieve	Indiana-Illinois Basin Oil Co.			Dry hole
33	Greene	16	6 N	6 W	1,790	Pennsylvanian	L. Mississippian	Commonwealth Oil Co.			Dry hole
34	Greene	21	6 N	7 W	2,331	Pennsylvanian	Devonian	Midwest Development			Dry hole
35	Greene	2	7 N	4 W	1,410	Mississippian	Silurian	Ohio Oil Co.			Dry hole
36	Hamilton	32	20 N	6 E	925	Silurian	Trenton	E. P. Anderson			Dry hole
37	Harrison	5	2 S	4 E	925	Mississippian	Ordovician	A. E. Wenning			Dry hole
38	Huntington	22	29 N	8 E	1,219	Silurian	Trenton	Geo. Beauchamp			Dry hole
39	Jasper	4	29 N	5 W	908	Silurian	Trenton	National Petroleum Co.			Dry hole
40	Jasper	19	28 N	6 W	1,059	Devonian	Trenton	National Petroleum Co.			Dry hole

41	Jasper	26	29 N	5 W	991	Silurian	Trenton	National Petroleum Co.			Dry hole
42	Jasper	1	29 N	5 W	1,002	Silurian	Trenton	A. C. Thomas			Dry hole
43	Jasper	25	30 N	7 W	1,101	Silurian	Trenton	A. C. Thomas			Dry hole
44	Knox	11	1 N	11 W	2,020	Pennsylvanian	Ste. Genevieve	Hughes Petroleum Corp.			Dry hole
45	Knox	27	1 N	11 W	2,227	Pennsylvanian	Ste. Genevieve	C. L. Wingate			Dry hole
46	Knox	34	1 N	12 W	2,402	Pennsylvanian	Ste. Genevieve	Lloyd Kennedy			Dry hole
47	Knox	24	2 N	9 W	1,754	Pennsylvanian	Ste. Genevieve	C. M. Lane			Dry hole
48	Knox	21	2 N	11 W	1,970	Pennsylvanian	Ste. Genevieve	A. B. Taylor			Dry hole
49	Knox	23	2 N	11 W	1,903	Pennsylvanian	Ste. Genevieve	Midwest Dev. Co.			Dry hole
50	Knox	15	5 N	10 W	3,055	Pennsylvanian	Silurian	C. L. Maguire			Dry hole
51	Knox	Don. 75	3 N	9 W	1,689	Pennsylvanian	Ste. Genevieve	Amerlagene Inc.			Dry hole
52	Knox	Don. 75	3 N	9 W	866	Pennsylvanian	L. Penn.	Amerlagene Inc.			Dry hole
53	Knox	14	4 N	10 W	934	Pennsylvanian	L. Penn.	H. A. Sprowls			Dry hole
54	Knox	10	1 S	12 W	2,372	Pennsylvanian	Ste. Genevieve	Sam. C. Yingling			Dry hole
55	Lake	32	34 N	7 W	500	Devonian	Ordovician	Schentel Barritt Slaughter & Aiman			Dry hole
56	La Porte	33	36 N	1 W	1,368	Devonian	Trenton	Geo. Short			Dry hole
57	Martin	10	3 N	4 W	740	Pennsylvanian	St. Louis	Collier & Burton			Dry hole
58	Monroe	34	7 N	1 E	1,830	Mississippian	Trenton	Bunting & Deskins			Dry hole
59	Newton	22	27 N	8 W	1,075	Mississippian	Trenton	National Petroleum Co.			Dry hole
60	Newton	36	30 N	9 W	1,001	Devonian	Trenton	A. C. Howes			Dry hole
61	Newton	5	31 N	8 W	1,125	Silurian	Trenton	R. Heber Smith			Dry hole
62	Orange	33	1 N	1 W	1,516	Pennsylvanian	Devonian	United States Oil			Dry hole
63	Parke	20	14 N	8 W	2,466	Pennsylvanian	Trenton	H. N. Oakley			Dry hole
64	Perry	5	5 S	3 W	622	Pennsylvanian	L. Chester	Chas. Dice			Dry hole
65	Perry	15	7 S	3 W	1,230	Pennsylvanian	L. Mississippian	H. E. Pollock			Dry hole
66	Pike	11	3 S	7 W	1,404	Pennsylvanian	Ste. Genevieve	Frank Ellison			Dry hole
67	Pike	16	3 S	7 W	1,151	Pennsylvanian	M. Chester	Dawson & Steed	65		Discovery Spurgeon
68	Porter	20	36 N	5 W	318	Devonian	Silurian	Joe Bander			Dry hole
69	Porter	27	37 N	5 W	1,247	Devonian	Trenton	Felix Jablonski			Dry hole
70	Posey	6	5 S	13 W	2,953	Pennsylvanian	Ste. Genevieve	Lewis & Lynch			Dry hole
71	Posey	13	7 S	13 W	1,133	Pennsylvanian	Pennsylvanian	Lindas & Bruell	20		Second Lamott pool well
72	Posey	25	7 S	13 W	2,150	Pennsylvanian	M. Chester	Brown, Nelson, Eslick			Dry hole
73	Posey	13	7 S	13 W	1,951	Pennsylvanian	U. Chester	Haynes Thomas Drill. Co.	55		Discovery Lamott
74	Posey	16	6 S	14 W	2,811	Pennsylvanian	McClosky	Whisenant & Bruell Trenchard	33		Discovery Welborne Switch
75	Posey	34	4 S	13 W	3,109	Pennsylvanian	McClosky	Baron Kidd	25		
76	Posey	8	5 S	13 W	3,086	Pennsylvanian	St. Louis	Gulf Refining Co.			Dry hole
77	Posey	14	5 S	14 W	3,082	Pennsylvanian	St. Louis	Sells Petroleum, Inc.			Dry hole
78	Posey	31	5 S	14 W	3,117	Pennsylvanian	St. Louis	Gulf Refining Co.			Dry hole
79	Posey	34	5 S	14 W	3,040	Pennsylvanian	Ste. Genevieve	Morgenstern Oil Co. Inc.			Dry hole
80	Posey	35	5 S	14 W	1,441	Pennsylvanian	L. Penn	The Carter Oil Co.			Dry hole
81	Posey	36	5 S	15 W	3,099	Pennsylvanian	Ste. Genevieve	Joe Dawson			Dry hole
82	Posey	27	6 S	13 W	2,507	Pennsylvanian	M. Chester	J. R. Less			Dry hole
83	Posey	1	6 S	14 W	1,338	Pennsylvanian	L. Penn	Doran & Yakey			Dry hole
84	Posey	8	6 S	14 W	3,106	Pennsylvanian	St. Louis	Gulf Refining Co.			Dry hole
85	Posey	17	6 S	14 W	2,825	Pennsylvanian	Ste. Genevieve	Lewis Prod. Co.			Dry hole
86	Posey	1	7 S	13 W	2,813	Pennsylvanian	St. Louis	Sinclair Wyoming			Dry hole
87	Posey	6	7 S	13 W	2,678	Pennsylvanian	L. Chester	Walter A. Martin			Dry hole
88	Posey	14	7 S	13 W	2,780	Pennsylvanian	St. Louis	Yost & Dye			Dry hole
89	Posey	1	7 S	14 W	2,887	Pennsylvanian	St. Louis	Carter Oil Co.	1,177		Discovery Mt. Vernon
90	Posey	7	7 S	14 W	2,954	Pennsylvanian	St. Louis	Cherry & Kidd			Dry hole
91	Posey	22	7 S	15 W	2,951	Pennsylvanian	St. Louis	John D. Davis	23		
92	Posey	26	7 S	15 W	2,771	Pennsylvanian	L. Chester	Johnson Oil & Refining Co.			Dry hole
93	Posey	23	8 S	15 W	2,908	Pennsylvanian	L. Chester	R. B. Martin			Dry hole
94	Pulaski	5	29 N	4 W	631	Silurian	U. Ordivician	W. D. Anderson		500,000	Old abd. Francesville pool
95	Ripley	4	8 N	10 E	901	Silurian	Trenton	Oscar Hughes		Gas	Small private well
96	St. Joseph	28	36 N	1 E	1,514	Devonian	Trenton	Ohio Oil Co.			Dry hole

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
97	St. Joseph	20	38 N	4 E	642	Mississippian	M. Devonian	John McLean			Dry hole
98	Spencer	19	7 S	7 W	1,088	Pennsylvanian	U. Chester	J. B. Miller			Dry hole
99	Spencer	10	8 S	6 W	1,075	Pennsylvanian	U. Chester	Doris McPherson			Dry hole
100	Spencer	33	5 S	5 W	1,237	Pennsylvanian	Ste. Genevieve	Cherry & Kidd			Dry hole
101	Spencer	32	6 S	7 W	996	Pennsylvanian	U. Chester	E. J. Goldschmidt	36		Hatfield outpost
102	Spencer	32	6 S	7 W	1,007	Pennsylvanian	U. Chester	S. D. Jarvis			Dry hole
103	Spencer	33	6 S	7 W	1,060	Pennsylvanian	U. Chester	E. J. Goldschmidt			Dry hole
104	Starke	18	32 N	4 W	800	Devonian	U. Ordovician	R. J. Violette			Dry hole
105	Starke	5	32 N	2 W	1,171	Devonian	Trenton	R. B. Tamblyn Dev. Co.			Dry hole
106	Starke	26	33 N	2 W	1,160	Devonian	Trenton	Black & Feutz			Dry hole
107	Steuben	25	36 N	13 E	1,000	Mississippian	Trenton	C. C. Goff			Dry hole
108	Sullivan	34	6 N	8 W	1,306	Pennsylvanian	Ste. Genevieve	Continental Oil Co.			Dry hole
109	Sullivan	17	6 N	9 W	1,373	Pennsylvanian	Ste. Genevieve	Sun Oil Co.			Dry hole
110	Sullivan	9	8 N	10 W	2,600	Pennsylvanian	Salem	J. W. Reynolds			Dry hole
111	Vanderburgh	4	6 S	10 W	1,002	Pennsylvanian	Mansfield (B. Penn)	W. R. White et al.			Dry hole
112	Vanderburgh	7	7 S	11 W	1,161	Pennsylvanian	Mansfield (B. Penn)	Truman Drake	25		Heusler outpost
113	Vanderburgh	16	7 S	11 W	2,562	Pennsylvanian	Ste. Genevieve	Paul Osborne	34½		Unnamed pool
114	Vigo	24	11 N	8 W	3,000	Pennsylvanian	Trenton	C. Dewitt Lukens			Dry hole
115	Vigo	16	12 N	10 W	2,045	Pennsylvanian	Silurian	D. R. Wooters			Dry hole
116	Vigo	14	10 N	8 W	2,206	Pennsylvanian	Silurian	Krauss-Ricketts & Paulsen			Dry hole
117	Warren	24	23 N	10 W	1,730	Pennsylvanian	Trenton	Detrick & Topf.			Dry hole
118	Warrick	10	7 S	8 W	1,946	Pennsylvanian	Ste. Genevieve	Yankeetown Dev. Co.			Dry hole
119	White	16	28 N	4 W	990	Silurian	Trenton	National Petroleum Co.			Dry hole
120	White	1	28 N	5 W	1,638	Silurian	St. Peter	Ohio Oil Co.			Dry hole

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1941	53	34
Number of oil wells completed during 1941	260	16
Number of gas wells completed during 1941	57	3
Number of dry holes completed during 1941	94	122

called the Johnson. The second attempt proved dry. A new field in the Hazleton area was opened in the McClosky at 1705 ft. Initial production was around 200 bbl. Two more producers have been completed and several new locations are staked. The North Francisco field was opened with the Brown-Creselius well, producing 24 barrels.

The Vernon pool opened in Vanderburgh County at approximately 1100 ft. in the Mansfield sandstone, about ½ mile east of the Heusler pool. Six successful wells were drilled in the area, with an average initial production of 25 to 30 bbl.

Spencer County opened the new Hatfield area with a discovery well of 100 bbl. in the Waltersburg sandstone, after several dry holes had been drilled in the same section. Six producing wells are now complete. The Tar Springs and Mansfield proved to be new pay horizons in the Caborn area, with an initial production of several new wells ranging above 100 barrels.

The Stendal prospect, in Pike County, completed the (Dawson-Steed) Patberg No. 1 well at 65 bbl. from the Cypress sand.

The Laconia gas field, Harrison County, completed six gas wells and three dry holes in the N. A. shale. The Decatur County field completed 12 producing Trenton gas wells. The Unionport field, in Randolph County, completed four Trenton producers.

Activity in the old Trenton area increased and 1 oil well, 13 gas wells and 7 dry holes were completed in 1941 (exclusive of Decatur and Randolph County fields). Initial production was not large, however. An attempt is being made to revive the old Horton oil field in Hamilton County, north of Indianapolis, where a 5-bbl. Trenton well was completed at 1056 ft. Another well is being drilled near by.

Interest continues to grow in the northern part of the state. The (so-called) Elkhart field, Elkhart County, completed a producing well in February in the Devonian, for 47 bbl. Since then, nine dry holes have been drilled in that general area. In August, the Anderson-Erb well was completed in Pulaski County for 500,000 cu. ft. of gas from the Niagaran. This is near the old Francisville field. It appears to be an isolated pocket in the area.

Daviess County opened the North Glendale gas field in the Cypress sand with a 600,000-cu. ft. well. Seven wells have since been completed for gas.

In several other areas of the state, small gas wells, showing prospect of new pools, were completed. Large blocks continue to be assembled in northern Indiana. Activity in this area during 1941 surpassed all other years in total number of core and production tests. All tests thus far have proved disappointing in terms of production. With the expansion of wildcatting brought about by recent Federal Government rulings, Indiana should continue its new discoveries through 1942.

The Oil Industry in Kansas during 1941

By W. A. Ver Wiebe*

Under the impetus of new demands caused by the defense program, the oil and gas industries of Kansas established new records during the year 1941. In all, 2113 wells were drilled, which compares favorably with the record total drilled in 1937. These 2113 tests resulted in 1446 oil wells, 76 gas wells and 592 dry holes. In all three categories there was an increase over the previous year, but unfortunately the most marked increase was in the dry holes. Nearly 80 per cent of the increase must be allocated to the drilling of unsuccessful tests. This was partly because of the increasing difficulty of finding new reserve areas and partly because of the erratic character of the production in the Arbuckle dolomite, which is now the main producing zone. Closer analysis of the totals reveals that western Kansas accounted for 1634 tests, of which 1186 were oil wells, 34 were gas wells and 415 were dry holes. The total potential initial daily production uncovered by the successful wells amounted to 1,691,000 bbl. of oil and 508,000,000 cu. ft. of gas. Both figures indicate a considerable decrease when compared with the preceding year; in 1940 the respective figures were 2,128,000 bbl. and 1,289,000,000 cu. feet.

In eastern Kansas a total of 479 wells were drilled. Among these, 260 were oil wells accounting for a daily initial potential production of 45,662 bbl. The new gas wells numbered 42 and added 290,438,000 cu. ft. per day to the gas potential production of the state. The remaining tests, 177 in number, were dry.

It is interesting and significant that almost half (791) of the total wells drilled in western Kansas were drilled by the independent operators. Among the large companies the Cities Service Oil Co. drilled 169 wells; the Stanolind Oil and Gas Co., 101; the Skelly Oil Co., 80; the Continental Oil Co., 99, and the Shell Petroleum Co., 63 wells. In eastern Kansas the independent operators drilled 406 out of the total of 479 wells. Among the major oil companies the Cities Service Oil Co. drilled 38; the Phillips Petroleum Co., 13, and the Sinclair-Prairie Oil Co., 11 wells.

The figures on relative percentages of dry holes to successful oil or gas wells are revealing. In western Kansas approximately one third of all wells drilled by the independent operators were dry holes. The major oil companies drilled approximately 844 wells in western Kansas, of which 678 were successful in finding either oil or gas. It thus appears that the major companies fared much better than the independents. In eastern Kansas the major companies drilled 73 wells of which 63 were successful in finding commercial quantities of oil or gas.

No less than 286 wildcat tests were put down in western Kansas and 72 in eastern Kansas, or 358 in all, during 1941. Considerably more than half of these were drilled by independent operators; 200 in western and 66 in eastern Kansas. An exploratory hole ½ mile or more from production is regarded as a wildcat well in Kansas.

On a percentage basis, approximately 75 per cent of all wildcat wells were failures; only 25 per cent found oil or gas in western

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* University of Wichita, Wichita, Kansas.

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TABLE 1.—*Producing Oil and Gas Fields in Kansas*

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
			OIL FIELDS						
			Barrels	Barrels					
Barber County			177,115	604,086	25				
Lake City, 7-31-13W	July 1937	160	11,876	55,926	1 1 1	Viola Arbuckle Simpson	4,435 4,607 4,530	5 4 11	Limestone Dolomite Sandstone
Medicine Lodge, 15-33-13W	Mar. 1937	80	2,622	45,703	2	Misener	4,845	2	Limestone
Skinner, 21-31-14W	Sept. 1941	40	None	None	1	Viola	4,531	5	Limestone
Sun City, 35-30-15W	Dec. 1941	40	None	None	1	Lans. K. C.*	4,344	11	Limestone
Whelan, 32-31-11W	Aug. 1934	700	161,697	502,457	18	Chat	4,355	29	Chert
Barton County			12,041,208	54,305,768					
Ainsworth, 26-16-13W	Dec. 1936	5,000	438,193	2,108,193	1 62	Oread Arbuckle	2,925 3,390	4 5	Limestone Dolomite
Ainsworth NW., 28-16-13	Apr. 1941	200	14,625	14,625	3 2	Lans. K. C. Arbuckle	3,140 3,391		
Ainsworth, W 5-17-13W	Aug. 1941	40	3,840	3,840	1	Arbuckle	3,358	3	Dolomite
Albert, 30-18-15W	Jan. 1935	1,600	118,033	660,533	18	Reagan	3,601	15	Sandstone
Beaver, 16-16-12W	Dec. 1934	1,200	135,490	983,593	6 24 1	Oread Arbuckle Reagan	2,900 3,348 3,335	6 3 6	Limestone Dolomite Sandstone
Beaver N., 4-16-12W	Oct. 1937	160	25,308	208,958	3	Arbuckle	3,316	10	Dolomite
Bird, 33-18-15W	Mar., 1940	40	3,215	6,115	1	Lamotte	3,508	2	Sandstone
Bloomer, 36-17-11W	Feb. 1936	4,600	2,121,404	8,832,826	34 1 187	Lans. K. C. Sooy Arbuckle	3,044 3,310 3,257	10 24	Limestone Conglomerate Dolomite
Davidson, 4-16-11W	Mar. 1928	300	20,000	66,500	3 2 4	Lans. K. C. Sooy Arbuckle	3,016 3,317 3,314	4 21 26	Limestone Conglomerate Dolomite
Eberhardt, 14-19-11W	June 1935	320	74,000	228,300	1 7	Lans. K. C. Arbuckle	3,094 3,311	6 49	Limestone Dolomite
Ellinwood N., 33-19-11W	July 1937	80	6,300	44,800	2	Arbuckle	3,328	22	Dolomite
Feist, 29-18-11W	Mar. 1936	40	4,830	50,856	1	Arbuckle	3,430	3	Dolomite
Feltes, 14-16-12W	Nov. 1939	500	192,250	251,475	13	Sooy Arbuckle	3,342 3,350	2 4	Conglomerate Dolomite
Hagan, 20-20-11W	Dec. 1938	80	16,730	31,060	2	Arbuckle	3,323	7	Dolomite
Hammer, 35-19-12W	Aug. 1940	40	4,600	8,050	1	Arbuckle	3,348	22	Dolomite
Harzman, 33-16-11W	Oct. 1939	400	61,200	63,600	10	Lans. K. C.	3,124	8	Limestone
Heiser, 16-19-14W	Aug. 1935	40	3,600	22,500	1	Lans. K. C.	3,228	25	Limestone
Hiss, 31-20-13W	Feb. 1936	200	45,900	289,100	5	Lans. K. C.	3,270	20	Limestone
Hoisington, 21-17-13W	Jan. 1938	160	27,200	83,100	1 2	Lans. K. C. Arbuckle	3,222 3,440	5 12	Limestone Dolomite
Kowalsky, 32-20-11W	Dec. 1941	40	None	None	1	Arbuckle	3,378	8	Dolomite
Kraft, 10-17-11W	Mar. 1937	5,000	712,800	1,668,800	89	Arbuckle	3,281	8	Dolomite
Kraft-Prusa E., 36-16-11W	Dec. 1941	40	None	None	1	Arbuckle	3,357	13	Dolomite
Krier, 30-16-11W	Oct. 1939	1,000	168,400	252,400	2 6 7 11 2	Topeka Shawnee Lans. K. C. Sooy Arbuckle	2,845 2,885 3,030 3,327 3,330		Limestone Limestone Limestone Conglomerate Dolomite
Kruckenberg, 14-19-15W	Jan. 1939	160			1 1	Lans. K. C. Arbuckle	3,342 3,580		Limestone Dolomite
Lanterman, 15-19-11W	Jan. 1935	400	106,200	315,400	6 4	Lans. K. C. Arbuckle	3,109 3,232	6 3	Limestone Dolomite
Odin, 10-17-12W	May 1938	80	990	14,440	1	Arbuckle	3,340	2	Dolomite
Pawnee Rock E., 17-20-15W	Nov. 1941	80	1,620	1,620	1	Arbuckle	3,814	5	Dolomite
Pospishel, 20-17-15W	June 1939	80	3,500	15,500	1	Arbuckle	3,548	9	Dolomite
Prusa, 20-16-11W	Dec. 1938	1,000	486,800	903,300	1 4 33 2	Topeka Lans. K. C. Arbuckle Reagan	 3,160 3,335 3,310	 7 1	 Limestone Dolomite Granite wash
Prusa NW., 18-16-11W	May 1939	600	97,470	157,875	1 12 2	Shawnee Lans. K. C. Arbuckle	 3,160 	 7 	 Limestone Dolomite
Prusa SE., 34-16-11W	Apr. 1940	80	6,800	9,800	2	Arbuckle	3,394	5	Dolomite
Rick, 1-19-11W	Aug. 1936	400	55,070	256,470	7 2	Lans. K. C. Arbuckle	3,106 3,355	18 2	Limestone Dolomite
Silica, 12-20-11W	Oct. 1931	32,000	7,062,900	36,747,900	10 783	Lans. K. C. Arbuckle	2,955 3,328	95 19	Limestone Dolomite
Stickney, 29-16-13W	Aug. 1941	120	None	None	3	Arbuckle	3,373	9	Dolomite

* Lansing Kansas City.

TABLE 1.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Straub, 36-18-11W	July 1934	40		4,239	1	Lans. K. C.	3,122	10	Limestone
Trapp (see Russell County)									
Butler County			5,617,680						
Augusta N., 28-27-4E	Jan. 1914	1,280	129,500	13,443,352	67	Bronson	1,900	35	Limestone
						Layton	2,000		
						Wilcox	2,380	10	Sandstone
						Arbuckle	2,410	5	Dolomite
Augusta S., 21-28-4E	Jan. 1916	9,000	311,000	33,806,600	152	Bronson	1,900		Limestone
						Ft. Scott	2,100		Limestone
						Wilcox	2,445	10	Sandstone
						Arbuckle	2,600	5	Dolomite
Bausinger, 24-27-3E	July 1929	200	8,640		5	Wilcox	3,050	29	Sandstone
Benton, 10-26-3E	Jan. 1925	80	3,000		2	Chat	2,765	5	Chert
Blankenship, 2-26-8E	Jan. 1921	1,200	70,000		88	Bartlesville	2,650	50	Sandstone
Brandt, 15-28-7E	June 1936	800	216,150	636,280	42	Chat	2,692	8	Chert
DeMoss, 5-28-7E	Oct. 1924	500	140,000		21	Bartlesville	2,700		Sandstone
						Burgess	2,732	10	
Douglass, 2-29-4E	Jan. 1916	2,500	120,000		37	Lans. K. C.	1,790	40	Limestone
						Varner	2,835	50	Chert
Eckels, 7-27-7E	Aug. 1940	120		18,680	3				
Elbing, 8-23-4E	Aug. 1918	1,800	420,000		74	Lans. K. C.	2,330	70	Limestone
						Viola	2,530	40	
El Dorado, 29-25-5E	Jan. 1917	25,000	3,028,900	179,899,180	1,562	Admire	600	10	Sandstone
						Lans. K. C.	1,700	20	Limestone
						Viola	2,500	5	Limestone
						Simpson	2,510	15	Sandstone
						Arbuckle	2,550	5	Dolomite
Ferrell, 28-28-8E	Mar. 1939	180	46,450	83,250	8	Miss.†	2,647	42	Limestone
Fox Bush, 25-28-5E	Jan. 1917	5,000	120,000		148	Bartlesville	2,730	40	Sandstone
Garden, 32-26-6E	Mar. 1928	1,600	54,000		31	Bartlesville	2,760	10	Sandstone
Gelwich, 6-27-4E	Apr. 1930	100	14,400		3	Viola	2,924	2	Limestone
Haverhill, (15-34)-27-5E	Apr. 1927	800	169,000	3,328,250	67	Bartlesville	2,700	50	Sandstone
Keighley, (14-33)-27-7E	Jan. 1925	1,800	63,600		45	Bartlesville	2,650	50	Sandstone
					3	Hunton	3,148	10	Limestone
Kramer, 4-28-6E	Jan. 1936	500	40,400		17	Viola	3,050	3	Limestone
						Wilcox	3,020	15	Sandstone
						Arbuckle	3,040	5	Dolomite
Leon, 19-27-6E	Oct. 1926	500	26,400		21	Chat	2,660	50	Chert
						Viola	3,050		Limestone
McCullough, 1-28-6E	Feb. 1926	400	36,600	393,889	8	Wilcox	3,169	6	Sandstone
Potwin, 36-24-3E	Jan. 1921	4,000	252,000		90	Bronson	2,550	5	Limestone
						Miss.	2,660	95	Limestone
Shaffer, 4-27-6E	June 1926	1,000	96,200		27	Miss.	2,760	10	Limestone
						Viola	3,125	25	Limestone
Seward, 14-27-7E		600	12,960	959,560	14	Bartlesville	2,650	50	Sandstone
Smock-Sluss, 19-26-6E	Mar. 1918	1,500	58,100		43	Bartlesville	2,685	30	Sandstone
						Viola	3,000		
Snowden-McSweeney, 2-29-6E	1930	160	3,800		1	Miss.	2,833		Limestone
Steinhoff, 21-29-6E	Jan. 1926	160	4,180		3	Chat	2,803	5	Chert
Stern, 27-27-6E	Jan. 1928	700	95,400		20	Chat	2,752	8	Chert
						Viola	3,150		
Weaver, 1-28-5E	Jan. 1929	400	5,000		5	Bartlesville	2,690		Sandstone
Young, 27-26-7E	1919	900	72,000		31	Lans. K. C.	2,190	5	Limestone
						Chat	2,650	50	Chert
Clark County									
Morrison, 17-32-21W	Oct. 1936	160	12,150	124,700	2	Viola	6,467	4	Limestone
Coffey County									
Van Noy, (1-14)-23-14E, (6-18)-23-15E		700	17,500		35	Peru	1,138	12	Sandstone
						Chat	1,623	6	Chert
Cowley County			2,716,960						
Baird, 16-34-3E		160	4,000		2	Bartlesville	3,260		Sandstone
Baird E., 15-34-3E	July 1940	40	3,000	4,950	1	Bartlesville	3,265	15	Sandstone
Biddle, 12-32-4E		600	35,000		22	Stalnaker	2,300	20	Sandstone
						Lans. K. C.	2,600	10	Limestone
Brown, 13-31-7E	Sept. 1922	40	2,900	202,900	1				
Bruce, 9-30-4E	Aug. 1941	40	690	690	1	Burbank	3,315		Sandstone
Burden, 22-31-6E	Jan. 1926	1,200	49,300		32	Bartlesville	2,865	35	Sandstone
Carson, 19-32-3E	Oct. 1924	400	62,900	3,112,558	16	Layton	2,600		Sandstone
						Arbuckle	3,450		Dolomite
Clarke, 6-31-4E	Jan. 1914	180	10,000		4	Bartlesville	2,840		Sandstone
Clover, 17-31-7E	Sept. 1940	40		4,350	1				

† Mississippi lime.

TABLE 1.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Couch, 13-30-5E........	May 1937	400	144,500	197,500	18	Burbank	2,835	5	Sandstone
Countryman, 4-33-7E...		600	6,100		5	Layton	1,950		Sandstone
Darien, 33-30-4E.......	June 1939	200	50,850	114,486	6	Arbuckle	3,286	1	Dolomite
David, 35-30-4E........	July 1935	900	121,900	563,676	24	Bartlesville	2,935	40	Sandstone
David S., 11-31-4E, 2-31-4...............	Jan. 1934	200	11,350	91,850	5	Bartlesville	3,010	19	Sandstone
					1	Arbuckle	3,463	3	Dolomite
Deichman, 24-31-4E....	Dec. 1941	40	None	None	1	Bartlesville	2,835	1	Sandstone
Dexter, 24-33-6E.......	Jan. 1903	1,200	1,600		1	Miss.	2,750		Limestone
Dunbar, 29-30-5E.......	Sept. 1938	40	720	6,820	1	Bronson	2,229	36	Limestone
Eastman, 31-30-6E......	Jan. 1924	1,200	46,800	2,379,124	33	Bartlesville	2,770	100	Sandstone
Falls City, 17-35-7E.....	Jan. 1916	600	19,100	1,183,076	8	Stalnaker	2,000		Sandstone
Ferguson W., 21-30-8E..	Oct. 1934	200	10,130		10	Bronson	2,181	5	Limestone
Frog Hollow, 20-32-5E..	Jan. 1937	900	232,000	697,056	36	Bartlesville	3,089	8	Sandstone
Frog Hollow E., 15-31-5E	Apr. 1941	120	5,540	5,540	3	Bartlesville	3,060	8	Sandstone
Geuda Springs, 8-34-3E..	May 1936	600	31,000	219,950	10	Bartlesville			Sandstone
					1	Chat	3,320		Chert
Gibson, 29-34-3E.......	Feb. 1941	200	15,330	15,330	5	Bartlesville	3,360	14	Sandstone
Graham, 9-33-3E.......	June 1924	800	24,800	2,491,340	9	Layton	2,550		
						Arbuckle	3,500		Dolomite
Grand Summit, 10-31-8E	July 21, 1926	600	19,600		13	Bronson	1,913	19	Limestone
Hanna, 4-30-8E.........	Dec. 1936	80	2,100	5,190	2				
Hittle, 21-31-4E........	Jan. 1926	2,400	833,000	3,199,300	73	Stalnaker	2,400		
						Arbuckle	3,280	8	Dolomite
Hower, 32-33-3E........	Dec. 1935	80		17,474	2				
Mahannah, 6-30-8E.....	1918	80	2,500	36,920	2	Burgess	2,730		Conglomerate
Murphy, 8-35-3E.......	Jan. 1933	600	25,700		12	Chat	3,300		Chert
Olsen, 1-35-7E..........	Apr. 1921	300	3,800		4	Ft. Scott	2,400		Limestone
Rahn, 13-34-5E.........	Oct. 1939	40	8,100	16,230	1	Bartlesville	2,915	30	Sandstone
Rainbow Bend, 20-33-3E	Dec. 1923	2,000	327,900	13,328,546	115	Burgess	3,200	50	Sandstone
Reidy, 31-31-8E........		160	3,000		3	Bronson	1,950	10	Limestone
Rock, 15-30-4E..........	Jan. 1923	500	57,800	1,516,800	27	Bartlesville	2,760	45	Sandstone
Rock West, 16-30-4E....	Oct. 1937	200	150,200	410,679	12	Bartlesville	2,784	18	Sandstone
Rock North, 3-30-4E....	Sept. 1937	200	14,350	65,023	5	Bartlesville	2,807	21	Sandstone
Smith, 10-31-3E........	Jan. 1917	600	7,000		9	Bartlesville	3,050		Sandstone
State, 15-32-4E.........	Jan. 1926	1,500	55,000		30	Layton	2,300		Sandstone
						Arbuckle	3,500		Dolomite
Trees, 19-30-4E.........	Jan. 1934	300	24,000		10	Bartlesville	2,975	25	Sandstone
Turner, 30-32-6E.......	June 1937	240	28,000	166,998	6	Layton	2,332	15	Sandstone
Udall, 28-30-3E.........		40	2,900	50,460	1				
Weathered, 28-31-3E....	July 1935	1,000	165,600	2,057,400	1	Stalnaker			
					2	Lans. K. C.	2,455		Limestone
					2	Miss.	3,065	85	Limestone
					24	Arbuckle	3,400		Dolomite
Winfield, 36-32-4E......	Nov. 1914	5,000	96,900		60	Admire	600		Sandstone
						Peacock	1,400		Sandstone
						Layton	2,300		Sandstone
						Bartlesville			Sandstone
						Arbuckle			Dolomite
Elk County.................			302,364						
Batesman, 24-28-11E....	July 1941	40	None	None	1	Bronson	1,096	2	Limestone
Bush-Denton, 3-30-9E...	1921	900	36,500		33	Stalnaker	1,060	10	Sandstone
					10	Burgess	2,297	5	Conglomerate
Collyer, 25-30-10E......	Mar. 1924	300	8,000		8	Ft. Scott	1,518	10	Limestone
Dory, 19-30-9E.........	July 1921	120	1,900		3	Miss.	2,470	32	Limestone
Dunkelberger, 27-29-10E	Sept. 1920	600	55,000		15	Bronson	1,358	10	Limestone
					5	Miss.	1,970	39	Limestone
Ferguson E., 23-30-8E...	1921	100			1	Bronson	2,100	5	Limestone
					2	Arbuckle		3	Dolomite
Key, 26-31-10E.........	1928	250			7	Bronson	1,270	14	Limestone
						Ft. Scott	1,624	4	Limestone
						Arbuckle		5	Dolomite
Mills, 23-30-10E........	Apr. 1927	160	1,800		4	Miss.	2,035	10	Limestone
Moline, 3-31-10E.......	Dec. 1927	5,000	12,600		25	Encill.	1,150		Sandstone
						Miss.	1,980		Limestone
Oliver, 35-31-10E.......	Apr. 1926	120	1,200		2	Ft. Scott	1,686	14	Limestone
					1	Arbuckle			Dolomite
Porter, 12-29-8E........	Mar. 1923	360	17,500		8	Bronson	2,045	10	Limestone
					3	Arbuckle		4	Dolomite
Rettig, 19-31-10E.......	Jan. 1926	40			1	Bronson	1,524	13	Limestone
Sellars, 11-31-9E........	July 1937	80		15,721	2	Miss.	2,300	22	Limestone
Severy, 16-28-11E......	Mar. 1922	2,000	58,800		49	Bronson	1,159	13	Limestone
Walker, 5-31-10E........	July 1927	120	2,500		2	Bronson	1,568	10	Limestone
					1	Miss.	2,008	15	Limestone

TABLE I.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Webb, 28-31-10E.......	Oct. 1924	3,600	102,000		92	Encill.	110		Sandstone
						Red	1,350		Sandstone
						Ft. Scott	1,650		Limestone
						Arbuckle	2 286		Dolomite
Youngmeyer, 25-28-8E..	Aug. 1941	80	4,564	4,564	2	Arbuckle	2,913	4	Dolomite
Ellis County................			8,740,076	25,575,545					
Bemis-Shutts, 16-11-17W	Oct. 1935	12,000	4,238,000	15,944,700	425	Arbuckle	3,380	2	Dolomite
Bemis South, 2-12-17W..	Dec. 1938	40	8,700	25,810	1	Arbuckle	3,592	11	Dolomite
Blue Hill, 14-12-16W....	Aug. 1937	700	194,950	374,450	3	Topeka	3,030		Limestone
					14	Lans. K. C.	3,072	33	Limestone
					1	Wilcox	3,391	1	Sandstone
					2	Arbuckle	3,360	25	Dolomite
Burnett, 1-11-18W......	Sept. 1937	5,000	3,347,500	5,446,000	2	Lans. K. C.	3,350	8	Limestone
					203	Arbuckle	3,570	4	Dolomite
Catherine, 3-13-17W....	June 1936	160	11,100	123,700	2	Lans. K. C.	3,262	88	Limestone
Emmeram, 4-13-16W....	June 1937	160	18,400	64,512	4	Lans. K. C.	3,260	7	Limestone
Hadley, 20-11-17W	Aug. 1929	40	172	58,562	1	Lans. K. C.	3,428	12	Limestone
Haller, 10-11-18W......	July 1936	40	600	13,860	1	Topeka	3,036	9	Limestone
Herzog, 30-13-16W......	June 1940	120	41,400	48,140	3	Arbuckle	3,450	8	Dolomite
High Spot, 28-12-16.....	Feb. 1941	40	2,694	2,694	1	Arbuckle	3,620	6	Limestone
Koblitz, 23-12-18W.....	Feb. 1937	800	88,400	132,707	8	Arbuckle	3,694	4	Dolomite
Kraus, 22-14-9W.......	July 1936	100	6,500	58,900	2	Sooy	3,735	5	Conglomerate
Marshall, 36-11-18W....	Nov. 1936	1,000	186,250	653,750	18	Arbuckle	3,638	12	Dolomite
Penny Wahn, 13-15-20W	Sept. 1936	40	8,200	34,100	1	Sooy	3,653	3	Conglomerate
Richards, 5-11-18W.....	Jan. 1938	120	14,250	81,150	2	Lans. K. C.	3,332	41	Limestone
Ruder, 17-15-18W......	Aug. 1935	700	60,350	692,950	12	Lans. K. C.	3,422	18	Limestone
					2	Arbuckle	3,572	10	Dolomite
Solomon, 28-11-19W....	June 1936	160	30,400	78,800	3	Arbuckle	3,629	3	Dolomite
Sugar Loaf, 17-13-17W..	Mar. 1941	80	10,325	10,325	2	Arbuckle	3,645	9	Dolomite
Sugar Loaf SE., 28-13-17W...............	Sept. 1941	40	2,935	2,935	1	Lans. K. C.	3,312	8	Limestone
Toulon, 3-14-17W.......	Dec. 1935	200	26,050	173,900	4	Lans. K. C.	3,298	5	Limestone
					1	Arbuckle	3,512	48	Dolomite
Ubert, 12-13-18W.......	Nov. 1936	160	31,550	155,050	5	Arbuckle	3,707		Dolomite
Walter, 2-12-18W.......	May 1936	1,400	411,350	1,398,550	1	Topeka	3,160	5	Limestone
					41	Arbuckle	3,619		Dolomite
Ellsworth County............			3,214,400	17,638,899					
Breford, 7-17-10W......	Sept. 1932	1,200	119,400	1,259,950	8	Lans. K. C.	3,140	12	Limestone
					20	Arbuckle	3,368	27	Dolomite
Lorraine, 13-17-9W.....	Nov. 1934	5,500	461,800	8,288,950	30	Lans. K. C.	3,060	140	Limestone
					59	Arbuckle	3,200	5	Dolomite
Stoltenberg, 22-16-10W..	June 1931	5,200	1,874,100	6,607,222	158	Arbuckle	3,333	14	Dolomite
Stoltenberg SW., 20-16-10W...............	July 1940	320	11,600	15,470	8	Arbuckle			
Wilkins, 13-17-10W.....	Apr. 1934	3,600	747,500	1,467,307	62	Arbuckle	3,260	20	Dolomite
Finney County..............									
Nunn, 27-21-34W.......	June 1938	800	27,850	114,955	2	Miss.	4,654	10	Limestone
Graham County.............			127,917	239,567					
Gettysburgh, 7-8-23W...	Sept. 1941	40	1,017	1,017	1	Lans. K. C.	3,725	30	Limestone
Morel, 15-9-21W........	Apr. 1938	1,200	114,800	226,300	7	Arbuckle	3,718		Dolomite
Penokee, 11-8-24W......	Nov. 1940	40	12,100	12,250	1	Lans. K. C.	3,750	6	Limestone
Greenwood County...........			3,399,000						
Atyeo-Pixlee, 6-22-10E..	Jan. 1923	1,000	165,000		93	Bartlesville	2,327	50	Sandstone
Beaumont, 25-27-8E....			179,000		19				
Blackwell, 16-24-13E....	Jan. 1923	1,000	2,500		5	Miss.	2,327		Limestone
Brinegar, 32-26-13E.....		500	6,100		31				
Browning, 8-22-10E.....	Jan. 1924	3,800	148,000		93	Bartlesville	2,314	76	Sandstone
Burkett, 13-23-10E.....	Jan. 1924	2,700	85,000		103	Bartlesville	2,000	100	Sandstone
Christy, 36-24-12E......		2,200	2,500		8	Bartlesville	1,500	75	Sandstone
DeMalorie-Souder, 19-21-10E................	Jan. 1924	4,500	317,000		129	Bartlesville	2,150		Sandstone
Dunaway, 4-22-13E.....		1,000	52,000		47	Miss.	1,800		Limestone
Eureka, 35-25-10E......	Jan. 1920	1,200	14,300		11	Miss.	2,000		Limestone
Fankhouser, 32-21-12E..	Jan. 1926	2,500	45,000		63	Bartlesville	1,750		Sandstone
Gaffney, 6-24-11E......	Aug. 1926	500	11,000	245,500	3				
Hamilton, 26-23-11E....	Jan. 1929	3,000	113,000		92	Bartlesville	1,765	72	Sandstone
Hinchman, 17-24-13E...		200	12,000		13	Miss.	1,600	50	Limestone
Keller, 22-26-13E.......	Apr. 1941	250	12,500	12,500	6				
Lamont, 5-22-12E.......	Jan. 1927	2,600	120,000		111	Bartlesville	1,650		Sandstone
Madison, 1-22-11E......	Jan. 1921	3,000	176,000		103	Bartlesville	1,800		Sandstone
Polhamus, 27-24-9E.....	Jan. 1922	1,400	22,000		46	Bartlesville	2,170		Sandstone
Quincy, 18-25-14E......	Jan. 1926	3,600	180,000		110	Bartlesville	1,420		Sandstone
Reece, 21-26-9E........		1,500	45,000		27	Miss.	2,100		Limestone

TABLE I.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Sallyards, 17-25-9E	Jan. 1921	8,000	125,000		133	Bartlesville	2,350	150	Sandstone
Scott, 19-23-9E	Jan. 1925	2,500	105,000		71	Bartlesville	2,525	75	Sandstone
Seeley-Wick, 22-22-11E	Jan. 1922	7,000	345,000		329	Bartlesville	1,930	45	Sandstone
Smith-Jobe, 10-24-13E	Sept. 1938	40	1,600		1	Miss.	1,662	3	Limestone
Teeter, 36-22-9E	Jan. 1922	4,000	241,000		197	Bartlesville	2,400	150	Sandstone
Teichgraber, 2-25-8E		900	18,500		21	Bartlesville	2,450		Sandstone
Thrall, 28-23-10E	1921	7,000	270,000		278	Bartlesville	2,190	166	Sandstone
Virgil, 13-24-12E	Jan. 1916	4,800	108,000		104	Bartlesville Burgess Miss.	1,550 1,700 1,700	10	Sandstone Conglomerate Limestone
Virgil N., 3-23-13E		8,000	414,000		292	Bartlesville Miss.	1,550 1,700		Sandstone Limestone
Wiggins, 7-24-11E	Jan. 1925	2,500	44,000		45	Bartlesville	1,860	15	Sandstone
Wilkerson, 6-25-9E		1,300	13,000		13	Bartlesville	2,300		Sandstone
Willard, 7-27-11E		1,000	6,000		4				
Harvey County			687,600	20,417,311					
Halstead, 36-22-2W	Apr. 1929	1,200	115,150	1,291,850	20	Chat	3,005	30	Chert
Hollow-Nikkel, 30-22-3W	Dec. 1931	1,500	523,100	18,784,807	86	Lans. K. C. Chat Hunton Simpson Arbuckle	2,499 3,195 3,507 3,500	21 13 2 14	Limestone Chert Limestone Sandstone
Sperling, 23-22-2W	Jan. 1935	500	49,350	340,654	8	Hunton Simpson	3,279 3,447	66 16	Limestone Sandstone
Kearny County									
Patterson, 23-22-38W	Aug. 1941	80	8,127	8,127	2	Patterson	4,748	4	Sandstone
Kingman County									
Cunningham, 30-27-10W	Jan. 1931	1,400	512,700	2,718,703	74 8	Lans. K. C. Viola	3,390 3,925	74 33	Limestone Limestone
Marion County			1,019,000						
Covert-Sellers, 1-21-4E	Sept. 1920	2,400	56,000		16	Viola	2,330	5	Limestone
Florence, 20-21-5E	Dec. 1929	3,000	33,200		18	Viola	2,300	10	Limestone
Hillsboro, 12-19-2E	Oct. 1927	300	60,400	1,821,484	10	Viola	2,800		Limestone
Lost Springs, 22-17-4E	Sept. 1926	2,400	840,000		116	Chat	2,365		Chert
Peabody, 5-22-4E	Sept. 1929	3,000	29,400		26	Viola	2,532		Limestone
McPherson County			4,228,160	72,593,311					
Bitikofer, 1-20-1W	May 1940	80	7,200	8,360	2	Chat	2,911	24	Chert
Bornholdt, 30-20-5W	Aug. 1937	2,600	701,100	2,608,500	150	Chat	3,292	43	Chert
Canton North, 28-18-1W	July 1936	80	10,200	68,468	2	Chat	2,803	29	Chert
Chindberg, 18-19-2W	Jan. 1929	700	84,950	1,308,310	5 25	Lans. K. C. Chat	2,363 3,007		Limestone Chert
Graber, 32-21-1W	May 1934	2,800	964,650	6,005,028	3 2 130 1	Chat Misener Hunton Simpson	 3,323 3,274 3,398	 3 24 8	Chert Sandstone Limestone Sandstone
Henne, 21-17-1W	Nov. 1940	280	26,500	27,320	7	Chat	2,658	4	Chert
Johnson, 35-19-3W	Feb. 1932	1,200	79,700	2,627,865	16	Chat	3,032	14	Chert
Lindsborg, 8-17-3W	Jan. 1938	160	18,300	65,632	3	Viola	3,352	21	Limestone
McPherson, 29-18-2W	Sept. 1926	2,000	57,150	924,735	29	Lans. K. C. Chat Viola	2,340 2,967 3,140	55 11 6	Limestone Chert Limestone
Ritz-Canton, 1-20-2W	July 1929	13,000	1,355,200	34,905,573	248	Lans. K. C. Chat Viola Simpson	2,360 2,935 3,412 3,440	39 31 2 4	Limestone Chert Limestone Sandstone
Roxbury, 18-17-1W	Nov. 1938	500	332,505	511,252	37	Chat	2,684	5	Chert
Voshell, 9-21-3W	Aug. 1929	3,500	590,400	23,532,268	102	Chat Viola Simpson Arbuckle	3,095 3,301 3,322 3,394	15 3 3 10	Chert Limestone Sandstone Dolomite
Ness County									
Aldrich, 7-18-25W	Oct. 1929	2,000	115,300	355,656	13	Ft. Scott Miss.	4,378 4,428	21 2	Limestone Limestone
Norton County									
Hewitt, 11-4-21W	July 1941	40	3,707	3,707	1	Lans. K. C.	3,404	3	Limestone
Pawnee County									
Pawnee Rock, 13-20-16W	Sept. 1936	2,400	178,000	311,162	25	Arbuckle	3,825	16	Dolomite
Phillips County			200,836	219,761					
Bow Creek, 25-5-18W	May 1939	40	6,550	17,475	1	Lans. K. C.	3,111	53	Limestone
Dayton, 36-2-19W	June 1941	120	7,086	7,086	2	Lans. K. C.	3,430	8	Limestone
Ray, 32-5-20W	Aug. 1940	1,200	187,200	195,200	29	Lamotte	3,540	13	Sandstone
Pratt County			86,950	174,686					
Cairo, 7-28-11W	Dec. 1939	160	30,650	40,118	4	Viola	4,267	16	Limestone

TABLE 1.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Iuka, 11-27-13W	Aug. 1937	640	56,300	134,568	6	Simpson	4,292	7	Dolomite
					1	Arbuckle	4,354	13	Dolomite
Reno County			3,237,603	38,400,996					
Abbyville, 24-24-8W	Jan. 1927	1,200	35,750	408,628	8	Lans. K. C.	3,540	9	Limestone
Buhler, 25-22-5W	Apr. 1938	500	67,000	364,959	1	Viola	3,890	19	Limestone
					9	Simpson	3,897	5	Sandstone
Burrton, 23-23-4W	Feb. 1931	5,000	2,523,700	33,093,107	336	Chat	3,266	42	Chert
					65	Hunton	3,583	6	Lime
						Arbuckle	3,775	9	Dolomite
Friendship, 30-25-4W	Nov. 1941	40	1,240	1,240	1	Viola	3,981	5	Limestone
Hilger, 16-26-4W	Mar. 1934	600	274,100	2,037,559	32	Viola	4,062	5	Limestone
Lerado, 11-26-9W	Dec. 1935	1,800	257,800	2,348,470	1	Lans. K. C.	3,535	4	Limestone
					32	Viola	4,128	28	Limestone
Peace Creek, 21-23-10W	July 1941	1,000	73,216	73,216	23	Viola	3,773	3	Limestone
Peace Creek NE., 11-23-10W	Dec. 1941	120	1,347	1,347	3	Viola	3,757	3	Limestone
Yoder, 34-24-5W	Oct. 1935	500	3,450	72,470	5	Chat	3,450	51	Chert
Schweizer, 31-22-9W	Dec. 1941	40	None	None	1	Viola	3,720	5	Limestone
Rice County			7,686,178	58,810,408					
Bornholdt W., 36-20-6W	Nov. 1941	40	423	423	1	Chat	3,330	40	Chert
Bowman, 21-19-10W	July 1936	160		21,791	4	Lans. K. C.	3,032	10	Limestone
					1	Arbuckle			
Brandenstein, 10-19-10W	Nov. 1933	160	14,300	374,251	2	Lans. K. C.	3,014	12	Limestone
Bredfeldt W., 12-18-10W	Dec. 1939	80	10,325	24,325	2	Arbuckle	3,260	8	Dolomite
Campbell, 28-19-9W	Jan. 1938	800	238,800	932,150	3	Lans. K. C.	3,195	13	Limestone
					22	Arbuckle			Dolomite
Chase, 32-19-9W	Mar. 1931	5,200	2,030,050	22,412,741	11	Lans. K. C.	2,942	12	Limestone
					243	Arbuckle	3,246	38	Dolomite
Doran, 13-19-10W	Sept. 1936	250	28,600	134,514	5	Arbuckle	3,291	20	Dolomite
Edwards, 3-18-8W	Jan. 1936	2,600	838,100	2,960,598	90	Arbuckle	3,278	5	Dolomite
Geneseo, 25-18-8W	May 1934	5,600	1,938,100	7,028,200	1	Simpson	3,191	14	Sandstone
					191	Arbuckle	3,231	40	Dolomite
Guldner, 16-18-9W	July 1935	160	10,900	247,689	2	Lans. K. C.	2,884	41	Limestone
						Arbuckle	3,227	3	Dolomite
Haferman, 6-19-9W	June 1936	800	82,050	500,888	10	Arbuckle	3,192	24	Dolomite
Heinz, 8-18-10W	July 1938	80	13,050	39,552	1	Lans. K. C.	3,000	19	Limestone
					1	Arbuckle	3,254	14	Dolomite
Karber, 7-19-10W	Oct. 1940	120	21,200	27,430	3	Arbuckle	3,343	7	Dolomite
Keesling, 10-20-9W	Apr. 1935	1,200	420,400	3,033,161	65	Arbuckle	3,239	26	Dolomite
Lyons, 14-20-8W	Nov. 1939	40	3,250	10,237	1	Simpson	3,280	4	Dolomite
Midway, 8-20-9W	Apr. 1939	500	66,000	151,089	11	Arbuckle	3,244	19	Dolomite
Orth, 27-18-10W	July 1932	1,000	133,100	770,962	1	Shawnee			
					1	Lans. K. C.	2,915	21	Limestone
					11	Pre-Cambrian	3,240	3	Quartzite
Ploog, 33-18-9W	June 1930	300	74,600	1,241,370	10	Arbuckle	3,252	19	Dolomite
Ponce, 28-21-7W	Apr. 1936	40	3,950	29,337	1	Sooy	3,388	40	Conglomerate
Raymond, 21-20-10W	June 1929	1,200	464,050	6,255,903	20	Lans. K. C.	3,130	10	Limestone
					40	Arbuckle	3,330	21	Dolomite
Rickard, 22-18-9W	Oct. 1935	160	14,600	65,760	4	Arbuckle	3,324	41	Dolomite
Welch, 2-21-6W	Apr. 1924	1,500	93,200	4,293,850	24	Chat	3,370	44	Chert
Welch E., 1-21-6W	Oct. 1941	40	None	None	1	Chat	3,341	5	Chert
Welch N., 23-20-6W	June 1937	100	7,330	44,961	3	Chat	3,334	32	Chert
Wenke, 7-20-10W	Mar. 1935	400	85,700	341,722	11	Arbuckle	3,360	13	Dolomite
Wenke West, 18-20-10W	Oct. 1938	80	14,650	44,566	2	Arbuckle	3,292	5	Dolomite
Wherry, 11-21-7W	Sept. 1933	7,200	1,053,900	7,726,461	199	Sooy	3,358	22	Conglomerate
Wherry East, 12-21-7W	Sept. 1937	160	25,550	96,477	3	Sooy	3,455	14	Conglomerate
Rooks County			686,867	1,869,942					
Dopita, 31-8-17W	Apr. 1934	160	51,450	157,270	3	Lans. K. C.	3,212	5	Limestone
					4	Arbuckle	3,409	10	Dolomite
Erway, 2-10-16W	Aug. 1941	40	2,717	2,717	1	Lans. K. C.	3,136	40	Limestone
Faubin, 12-6-18W	Feb. 1936	80	4,300	42,200	2	Lans. K. C.	3,128	22	Limestone
Kruse, 3-10-16W	Jan. 1928	40	500	10,900	1	Lans. K. C.	3,115	6	Limestone
Laton, 11-9-16W	July 1927	1,000	521,850	1,093,996	71	Lans. K. C.	3,228	33	Limestone
Ray SE., 9-6-20W	Dec. 1941	40	None	None	1	Reagan	3,615	5	Sandstone
Webster, 21-8-19W	Oct. 1930	40	10,500	50,247	1	Arbuckle	3,434	1	Dolomite
Westhusin, 11-9-17W	Nov. 1936	400	83,750	394,563	12	Lans. K. C.	3,231	11	Limestone
Zurich, 26-10-19W	Sept. 1934	200	11,800	118,049	2	Lans. K. C.	3,340	9	Limestone
Rush County			160,300	1,602,826					
Otis, 10-18-16W	July 1934	800	158,500	1,555,397	22	Lamotte	3,527	9	Sandstone
Winget, 15-16-16W	Dec. 1936	80	1,800	47,429	3	Lans. K. C.	3,243	4	Limestone
					1	Arbuckle	3,537	8	Dolomite
Russell County			15,705,665	84,149,972					
Atherton, 30-13-14W	July 1935	1,800	223,150	1,098,064	8	Lans. K. C.	3,008	47	Limestone
					26	Arbuckle	3,284	5	Dolomite

TABLE 1.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Big Creek, 36-14-15W	July 1935	2,000	405,300	1,899,283	10	Lans. K. C.	2,908	42	Limestone
					40	Gorham	3,152	5	Sandstone
					16	Arbuckle	3,171	5	Dolomite
Big Creek E., 31-14-14W	July 1938	200	123,400	203,047	5	Lans. K. C.	3,180	15	Limestone
					3	Arbuckle	3,149	4	Dolomite
Boxberger, 36-15-15W	Dec. 1935	160	11,950	138,470	3	Lans. K. C.	3,147	4	Limestone
Bunker Hill, 31-13-12W	Oct. 1935	160	5,650	70,262	4	Lans. K. C.	2,965	16	Limestone
Davidson NE., 34-15-11W	Dec. 1940	80	10,042	10,042	2	Gorham	3,309	4	Sandstone
Dillner, 35-13-15W	May 1930	40		45,952	1	Arbuckle	3,300	8	Dolomite
Donovan, 10-15-15W	Feb. 1935	120	17,850	50,226	3	Lans. K. C.	3,193	7	Limestone
Driscoll, 30-15-11W	June 1940	80	11,450	15,450	1	Sooy	3,323	3	Conglomerate
					1	Arbuckle	3,255	5	Dolomite
					1	Lans. K. C.			
Dubuque, 34-15-12W	Oct. 1935	200	34,200	179,877	4	Arbuckle	3,275	3	Dolomite
Eichman, 34-15-13W	May 1935	800	32,950	648,965	9	Arbuckle	3,316	10	Dolomite
Fairfield, 22-15-13W	Dec. 1938	40	2,100	8,181	1	Arbuckle	3,352	5	Dolomite
Fairfield N., 16-15-13W	Jan. 1939	400	84,600	173,818	2	Lans. K. C.	3,112	5	Limestone
					8	Arbuckle	3,232	4	Dolomite
Fairport, 8-12-15W	Nov. 1923	3,600	573,100	15,015,974	147	Lans. K. C.	2,950	12	Limestone
						Gorham	3,211	5	Sandstone
Forest Hill, 29-15-12W	July 1941	160	8,296	8,296	4	Arbuckle	3,320	3	Dolomite
Gideon, 8-15-14W	June 1930	40		40,500	1	Sooy	3,266	7	Conglomerate
Gorham, 5-14-15W	Oct. 1926	7,500	2,426,100	19,460,548	1	Tarkio	2,525	25	Limestone
					10	Topeka	2,765	15	Limestone
					140	Lans. K. C.	3,027	30	Limestone
					2	Arbuckle	3,289	4	Dolomite
					156	Lamotte	3,299	1	Sandstone
Greenvale, 4-15-12W	Apr. 1938	1,600		376,600	19	Lans. K. C.	3,040	5	Limestone
					22	Arbuckle	3,267	21	Dolomite
Gustason, 14-15-12W	July 1941	80	2,334	2,334	2	Arbuckle	3,344	1	Dolomite
Hall-Gurney, 30-14-13W	Oct. 1931	19,000	3,535,350	9,516,698	2	Wabaunsee			Sandstone
					3	Topeka	2,675		Limestone
					396	Lans. K. C.	2,985	15	Limestone
					24	Gorham	2,965	4	Sandstone
					8	Arbuckle	3,451	3	Dolomite
					12	Lamotte	3,129	1	Sandstone
					3	Pre-Cambrian	3,156	25	Granite wash
Karst, 27-15-14W	Oct. 1935	160	25,300	198,250	3	Arbuckle	3,315	4	Dolomite
Lewis, 28-14-12W	Sept. 1940	40	5,580	7,150	1	Wabaunsee	2,317	12	Limestone
Mahoney, 8-14-12W	June 1940	120	22,100	24,400	3	Lans. K. C.	2,977	3	Limestone
Mohl, 18-14-13W	Oct. 1941	40	None	None	1	Lamotte	3,253	5	Sandstone
Neidenthal, 23-14-15W	Aug. 1934	600	38,600	880,748	2	Lans. K. C.			
					7	Arbuckle	3,246	4	Dolomite
Rusch, 29-14-14W	June 1941	240	30,663	30,663	2	Lans. K. C.	3,071	12	Limestone
					4	Arbuckle	3,216	8	Dolomite
Russell, 22-13-14W	Feb. 1934	1,200	427,500	4,810,746	3	Lans. K. C.	3,195	9	Limestone
					47	Arbuckle	3,280	6	Dolomite
Sellens, 26-15-13W	July 1929	1,200	217,650	2,578,623	1	Shawnee			
					8	Lans. K. C.	3,088	19	Limestone
					17	Arbuckle	3,352	13	Dolomite
Steinert, 21-15-15W	Mar. 1936	40	3,350	39,092	1	Lans. K. C.	3,060	36	Limestone
Trapp, 23-15-14W	Oct. 1939	28,600	7,126,000	25,461,806	1	Dodge			
					1	Topeka	2,889	7	Limestone
					108	Lans. K. C.	3,062	2	Limestone
					1	Sooy			Conglomerate
					677	Arbuckle	3,252	3	Dolomite
Trapp W., 15-15-14W	July 1939	500	58,300	95,213	12	Arbuckle	3,249	7	Dolomite
Vaughn, 17-14-14W	Apr. 1937	1,000	236,500	1,007,871	24	Lans. K. C.	3,004	30	Limestone
					1	Gorham	3,282	7	Sandstone
					4	Arbuckle			Dolomite
Williamson, 9-14-14W	Feb. 1936	160	6,300	52,823	2	Tarkio	2,522	28	Limestone
Scott County									
Shallow Water, 15-20-33W	Dec. 1934	600	137,150	1,039,612	9	Miss.	4,670	16	Limestone
Sedgwick County			1,106,670	43,691,046					
Cross, 29-25-1W	Apr. 1929	160	3,000	73,000	2	Lans. K. C.	2,690	40	Limestone
Eastborough, 19-29-2E	Aug. 1929	1,000	187,000	8,058,700	45	Chat	2,956	14	Chert
						Viola	3,238	4	Limestone
Eastborough N., 8-27-2E	Aug. 1938	80	1,400	4,400	1	Viola	3,258	4	Limestone
Goodrich, 16-25-1E	Dec. 1928	640	259,700	2,910,600	35	Lans. K. C.	2,614	2	Limestone
						Chat	3,010	10	Chert
						Misener	3,334	3	Limestone

TABLE 1.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Greenwich, 14-26-2E	May 1929	700	250,000	9,307,160	42	Chat Viola Simpson	2,885 3,321 3,350	3 5 4	Chert Limestone Sandstone
Kuske, 24-25-1E	Jan. 1929	40	2,250	139,690	1	Sooy	3,489	2	Conglomerate
Oatville, 18-28-1E	Nov. 1937	80	1,420	11,590	1	Simpson	3,489	2	Sandstone
Robbins, 20-28-1E	June 1929	420	81,150	2,959,547	52	Miss.	3,090	12	Limestone
Valley Center, 1-26-1W	Aug. 1928	1,500	320,750	20,226,359	66	Lans. K. C. Misener Viola	2,579 3,368 3,366	13 7 2	Limestone Limestone Limestone
Stafford County			5,454,693	15,510,599					
Ahnert, 26-22-13W	June 1941	40	5,917	5,917	1	Arbuckle	3,748	4	Dolomite
Bedford, 21-23-12W	Aug. 1940	640	174,100	181,929	17	Arbuckle	3,839	9	Dolomite
Drach, 12-22-13W	Nov. 1937	900	96,000	307,178	12	Arbuckle	3,693	12	Dolomite
Fischer, 31-21-12W	May 1938	120	37,250	111,914	3	Arbuckle	3,641	7	Dolomite
Gates, 27-21-13	May 1933	640	109,800	688,918	11	Arbuckle	3,679	39	Dolomite
Jordan, 15-25-14W	Nov. 1936	260	96,550	260,377	7	Lans. K. C.	3,722	5	Limestone
Kipp, 27-25-14W	Jan. 1937	220	63,800	145,000	7	Lans. K. C.	3,827	79	Limestone
Leesburgh, 12-25-13W	Apr. 1938	360	136,550	287,382	9	Arbuckle	4,153	10	Dolomite
Macksville, 3-24-15W	Mar. 1941	80	15,406	15,406	2	Lans. K. C.	3,811	16	Limestone
Max, 35-21-12W	Aug. 1938	200	72,000	123,433	1 8	Lans. K. C. Arbuckle	3,356 3,570	16 5	Limestone Dolomite
Mueller, 29-21-12	Mar. 1938	80	10,200	97,870	2	Arbuckle	3,594	7	Dolomite
Rattlesnake, 13-24-14W	Oct. 1938	40	10,450	30,148	1	Lans. K. C.	3,608	48	Limestone
Richardson, 36-22-12W	Oct. 1930	1,200	535,500	4,399,066	60	Arbuckle	3,537	62	Dolomite
Riley, 28-23-11W	Aug. 1940	40	9,770	11,961	1	Lans. K. C.	3,471	5	Limestone
Shaeffer, 3-21-13W	Mar. 1941	250	49,540	49,540	5 1	Lans. K. C. Arbuckle	3,404 3,546	4 4	Limestone Dolomite
St. John, 23-24-13W	Apr. 1935	1,200	252,200	955,868	14 10	Lans. K. C. Arbuckle	3,588 4,075	32 12	Limestone Dolomite
Sittner, 33-21-12	Aug. 1937	600	41,100	180,822	2 4	Lans. K. C. Arbuckle	3,278 3,600	36 6	Limestone Dolomite
Sittner S., 3-22-12W	May 1938	500	208,650	360,475	18	Arbuckle	3,594	6	Dolomite
Snider, 3-21-11W	Apr. 1936	320	27,500	198,270	4 2 2	Lans. K. C. Simpson Arbuckle	3,111 3,362 3,324	38 6 18	Limestone Sandstone Dolomite
Snider S., 16-21-11W	Aug. 1938	360	70,420	131,149	8	Simpson Arbuckle	3,402	7	Dolomite
Stafford, 15-24-12W	Aug. 1940	600	187,350	206,250	18 1	Viola Arbuckle	3,836 3,945	14 10	Limestone Dolomite
Zenith, 23-24-11W	Sept. 1937	5,000	3,244,640	6,761,726	301	Misener Viola	3,804 3,860	20 5	Sandstone Limestone
Sumner County			1,003,380	42,501,517					
Anness, 2-30-4E	Oct. 1937	40	7,600	44,298	1	Simpson	4,394	7	Sandstone
Caldwell, 17-35-3W	May 1929	160	66,000	1,338,950	4	Simpson	4,765	19	Sandstone
Churchill, 25-31-2E	July 1926	1,000	154,400	18,475,957	62	Stalnaker	1,820	25	Sandstone
Latta, 9-30-2W	June 1927	300	84,000	182,232	15	Lans. K. C.	3,042	14	Limestone
Oxford, 23-32-2E	Aug. 1927	800	206,700	14,489,875	13 6 21	Stalnaker Layton Arbuckle	2,020 2,890	16 14 3	Sandstone Sandstone Dolomite
Oxford W., 17-32-2E	May 1926	160	10,900	499,374	3	Arbuckle			Dolomite
Padgett, 23-34-2E	Oct. 1924	1,800	86,680	1,929,338	20	Chat	3,474	28	Chert
Rainbow Bend W., 24-33-2E		160	4,100	400,000	2	Burbank Arbuckle			Sandstone Dolomite
Rutter, 21-33-2E	July 1926	40	11,400	57,841	2	Chat	3,315	27	Chert
Vernon N., 15-35-2E	July 1915	200	33,850	250,996	5	Chat	3,443	22	Chert
Wellington, 33-31-1W	Dec. 1929	1,200	331,600	4,814,702	98	Chat	3,655	11	Chert
Zyba, 7-30-1E	Nov. 1937	80	6,150	17,954	2	Simpson	3,866	3	Sandstone
Trego County			45,050	447,773					
Gugler, 36-12-21W	Dec. 1936	40	1,950	20,278	1	Arbuckle	3,830	8	Dolomite
Ogallah, 10-12-21W	Nov. 1941	40	None	None	1	Arbuckle	3,992	5	Dolomite
Wakeeney, 14-11-23W	Oct. 1934	640	43,100	427,495	7	Lans. K. C.	3,619	8	Limestone
Woodson County			224,400						
Big Sandy, 14-26-14E	1926	800	11,500		20	Burbank	1,200	50	Sandstone
Hoagland, 2-24-14E	Mar. 1925	700	19,200		18	Miss.	1,620	37	Limestone
Wiede, 32-23-15E	Mar. 1922	400	3,700		7	Miss.	1,531	10	Limestone
Winterscheid, 15-23-14E		7,700	190,000		222	Bartlesville Miss.	1,575	15	Limestone

Kansas. Major companies and independent operators shared alike in this regard, for the percentages were 76 per cent failures for the former and 74 per cent for the latter. In eastern Kansas comparable data indicate that the failures ran slightly higher, at 77 per cent, the proportion for independents and major companies being about the same as in western Kansas.

Exploratory wells drilled at a distance of 2 miles or more from any known pool or well are often referred to as "rank wildcats." Classified in this manner, 147 of all wildcats in western Kansas fall into this category. Of this number 24 were successful in uncovering new oil or gas reserves. On a percentage basis, these figures indicate that only 19 per cent of the rank wildcat wells were successful in opening up new reserves. In eastern Kansas 37 wells can be classified as rank wildcats. Only two of these, or about 5 per cent, were successful. In summary, it appears that approximately three out of four of all wildcat wells drilled in Kansas are likely to result in dry holes and that among the rank wildcats approximately five out of six will be failures.

PRODUCTION

Oil.—Kansas reached an all-time high production record during 1941. From 21,838 wells approximately 82,500,000 bbl. of oil was produced. This represents an increase of nearly 18,000,000 bbl. over the previous year and of 13,000,000 bbl. over the previous record production in 1937. This notable increase was made possible

TABLE 1.—(*Continued*)

County, Field and Location	Discovery Date	Area, Acres	Production		Number Wells Producing	Producing Horizon			
			In 1941	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
			GAS FIELDS						
			M CU. FT.	M CU. FT.					
Barber County..............									
Medicine Lodge, 13-33-13W................	Jan. 1927	5,000	7,092,500	51,205,580	33	Chat	4,455	10	Chert
Barton County..............									
Albert................	See Otis in Rush County								
Bergtal, 22-20-15W.....	Sept. 1941	160			1	Arbuckle	3,367	10	Dolomite
Kruckenberg, 11-19-15W	Apr. 1941	160			1	Reagan	3,530	20	Sandstone
Edwards County									
McCarty, 31-25-17W....	May 1929	400	12,611		1	Sooy	4,545	10	Conglomerate
Harvey County..............									
Hollow-Nikkel..........	Dec. 1931	1,500	103,013		12	Chat	3,295	15	Chert
Sperling, 23-22-2W......	Jan. 1935	600	34,956	6,193,794	2	Chat	2,955	50	Chert
McPherson County..........			4,175,090						
Pratt County..............									
Cairo, 7-28-11W........	Nov. 1935	20,000	17,995,846	38,455,361	39	Viola	4,278	8	Limestone
Stark, 18-26-11W........	Apr. 1941	160			1	Viola	4,121	2	Limestone
Ward, 11-26-12W........	Dec. 1941	160			1	Viola	4,107	15	Limestone
Reno County..............									
Burrton, 23-23-4W......	Sept. 1930	5,000	4,533,164	46,131,128	52	Chat	3,298	70	Chert
Yoder, 34-24-5W........	Oct. 1936	800	428,507		4	Chat	3,402	50	Chert
Rice County									
Lyons, 35-19-8W........	July 1888	1,500	2,422,392	10,429,243	1	Simpson	3,290	10	Dolomite
					11	Arbuckle	3,277	10	Dolomite
Orth, 27-18-10W........	July 1933	640	519,515		3	Lans. K. C.	2,906	30	Limestone
Thurber, 22-21-9W......	Oct. 1937	400	3,358,303	4,959,890	7	Misener	3,317	10	Conglomerate
Rush County..............									
Otis, 11-18-16W........	Mar. 1930	15,000	8,988,337	63,124,237	60	Lamotte	3,507	2	Sandstone
Stafford County..............									
Hitz, 4-24-12W..........	Oct. 1941	40			1	Maquoketa	3,800	12	Dolomite
Sumner County..............									
Wellington, 33-31-1W...	Dec. 1929	1,200	696,832		97	Chat	3,655	12	Chert
Southwest Kansas...........									
Hugoton, 3-35-34W.....	1922	2 million	36,410,275	258,501,075	312	Winfield	2,755	10	Limestone
						Ft. Riley	2,800	8	Limestone
						Florence	2,850	10	Limestone

TABLE 2.—*New Pools Discovered in* 1941

County, Field and Location	Operator and Fee	Geologic Formation	Depth, Ft.	Month	Initial Production
OIL					
Barber County					BARRELS
Skinner, 21-31-14W	Deep Rock No. 1 Skinner	Viola	4,531–4,595	Sept.	40
Sun City, 35-30-15W	Pryor & Lockhart No. 1 Massey	Lans, K. C.	4,344–4,355	Dec.	3,000
Barton County					
Ainsworth NW., 28-16-13W	Continental No. 1 Stosskopf	Arbuckle	3,391–3,403	Apr.	539
Ainsworth W., 5-17-13W	Bartlett No. 1 Wondra	Arbuckle	3,358–3,361	Aug.	296
Kowalsky, 32-20-11W	Sinclair No. 1 Kowalsky	Arbuckle	3,378–3,384	Dec.	50
Kraft-Prusa E., 36-16-11W	Lynn No. 1 Kraft	Arbuckle	3,357–3,370	Dec.	55
Pawnee Rock E., 17-20-15W	Helm. & Payne No. 1 Unruh	Arbuckle	3,814–3,819	Nov.	583
Stickney, 29-16-13W	Mabee No. 1 Stosskopf	Arbuckle	3,373–3,390	Aug.	50
Cowley County					
Bruce, 9-30-4E	Trees Oil No. 1 Bruce	Burbank	3,315–3,320	Aug.	691
Deichman, 21-31-4E	Trees Oil No. 1 Deichman	Bartlesville	2,835–2,836	Dec.	78
Frog Hollow E., 15-31-5E	Tulsa Oil No. 1 Miller	Bartlesville	3,060–3,068	Apr.	302
Gibson, 29-34-3E	Sinclair No. 1 Gibson	Burbank	3,360–3,377	Feb.	90
Elk County					
Batesman, 24-28-11E	McPherson No. 1 "A" Batesman	Kans. City	1,096–1,098	July	15
Youngmeyer, 25-28-8E	Allison No. 1 Porter	Arbuckle	2,913–2,919	Aug.	25
Ellis County					
High Spot, 28-12-16W	Stearn Drill No. 1 Witt	Lans. K. C.	3,620–3,626	Feb.	680
Sugarloaf, 17-13-17W	Derby No. 1 Miller	Arbuckle	3,645–3,653	Mar.	462
Sugarloaf SE., 28-13-17W	Darby No. 1 "A" Dreiling	Lans. K. C.	3,312–3,320	Sept.	352
Graham County					
Gettysburg, 7-8-23W	Cities Service No. 1 Montgomery	Lans. K. C.	3,725–3,755	Sept.	70
Kearny County					
Patterson, 23-22-38W	Stanolind No. 1 Patterson	Patterson	4,748–4,752	Aug.	3,000
Norton County					
Hewitt, 11-4-21W	Phillips No. 1 Hewitt	Lans. K. C.	3,404–3,407	July	272
Phillips County					
Dayton, 36-2-19W	Carter No. 1 Freibus	Lans. K. C.	3,430–3,438	June	328
Reno County					
Friendship, 30-25-4W	Rocket Drill No. 1 Soper	Viola	3,981–3,986	Nov.	497
Hendrickson, 2-23-10W	Iron Drill No. 1 Hendrickson	Viola	3,736–3,744	Dec.	217
Peace Creek, 21-23-10W	Simpson Oil No. 1 Snowbarger	Viola	3,773–3,776	July	3,000
Peace Creek NE., 11-23-10W	Leader Oil No. 1 Tonn	Viola	3,757–3,760	Dec.	3,000
Schweizer, 31-22-9W	Hinkle No. 1 Schweizer	Viola	3,720–3,725	Dec.	
Rice County					
Bornholdt W., 36-20-6W	Westgate Greenland No. 1 Harder	Chat	3,330–3,370	Nov.	45
Welch East, 1-21-6W	Aladdin No. 1 Lackey	Chat	3,341–3,346	Oct.	278
Rooks County					
Erway, 2-10-16W	Cities Service No. 1 Erway	Lans. K. C.	3,136–3,205	Aug.	203
Ray Southeast, 9-6-20W	Derby No. 1 Steele	Reagan	3,600–3,620	Dec.	64
Russell County					
Forest Hill, 29-15-12W	Cent. Pete. No. 1 Steinle	Arbuckle	3,320–3,323	July	1,100
Gustason, 14-15-12W	Cent. Pete. No. 1 Gustason	Arbuckle	3,244–3,245	July	163
Mohl, 18-14-13W	ElDorado Ref. No. 1 Mohl	Reagan	3,253–3,258	Oct.	153
Rusch, 29-14-14W	Westgate Greenland No. 1 Rusch	Arbuckle	3,216–3,223	June	3,000
Stafford County					
Ahnert, 26-22-13W	Stanolind No. 1 Ahnert	Arbuckle	3,748–3,752	June	1,440
Macksville, 3-24-15W	Stanolind No. 1 Nagel	Lans. K. C.	3,811–3,827	Mar.	410
Shaeffer, 3-21-13W	Landon No. 1 Shaeffer	Lans. K. C.	3,404–3,408	Mar.	1,175
Trego County					
Ogallah, 10-12-21W	Shallow Water No. 1 Schaeffer	Arbuckle	3,992–3,997	Nov.	30
GAS					
					MILLION CU. FT.
Barton County					
Bergtal, 22-20-15W	Helm. & Payne No. 1 Schmidt	Arbuckle	3,667–3,692	Sept.	1,500
Kruckenberg, 11-19-15W	Schermerhorn No. 1 Merten	Reagan	3,530–3,550	Apr.	8,500
Marion County					
Robinson, 15-20-5E	Neb. & Wyo. No. 1 Robinson	Penn.	2,073–2,083		1,000
Pawnee County					
Zook, 16-23-16W	Stanolind No. 1 Smith	Arbuckle	4,066–4,068	Dec.	500
Pratt County					
Stark, 18-26-11W	Reeves No. 1 Stark	Viola	4,121–4,123	Apr.	21,000
Ward, 11-26-12W	Central No. 1 Ward	Viola	4,107–4,121	Dec.	4,000
Stafford County					
Hitz, 4-24-12W	Nelson Drill. No. 1 Hitz	Viola	3,800–3,812	Oct.	6,000

by the construction of pipe lines, of which no less than 13 different projects were completed during the year. Whereas most of these projects involve distances of only 6 to 12 miles, nevertheless they permitted connections to many previously shut-down fields. Their total capacity is close to 300,000 bbl. per day. The average production per well was 10.34 bbl. per day. Trapp pool, Russell County, again took the lead, with about 7,500,000 bbl. It was followed by the Silica pool, of southern Rice County, with about 7,000,000 bbl. and the Bemis-Shutts pool, of Ellis County, with somewhat over 4,000,000 bbl. Close behind came the Burnett pool, of Ellis County, and the Zenith pool, of southeastern Stafford County.

Gas.—The gas production in Kansas again established a new high record in 1941. Somewhat more than 100 billion cu. ft. is estimated to have been marketed from Kansas during 1941. The great bulk of this total came from southwestern Kansas from the Hugoton area. Here again the building of additional pipe lines explains part of the increase over the 90 billion of the previous year. Nine different projects were started during the year and of these all except two were completed. They range in length from a few miles to 220 miles (Globe Oil and Refining line from McPherson to Council Bluffs, Iowa). The proposed line from Hugoton to Milwaukee, Wis., is to be 770 miles long when completed.

NEW POOLS

According to the detailed list presented elsewhere in this report, 38 new oil pools and 7 new gas pools were discovered in Kansas during 1941. The most interesting of these new pools is the Patterson pool, in Kearny County, far to the west of any previously discovered pool. The discovery well was drilled on the Patterson Ranch by the Stanolind Oil and Gas Co. after several attempts on other near-by locations had proved unsuccessful. The Patterson well found saturation in a sandstone near the base of the Pennsylvanian system but was continued down to the Arbuckle dolomite. Later it was plugged back to the Pennsylvanian and shot between 4748 and 4752 ft., resulting in large initial production, rated officially at 3000 bbl. per day.

The new pools in western Reno County, the Peace Creek, Peace Creek NE., and Hendrickson, lie along a trend that many

TABLE 3.—*New Producing Zones Discovered in Old Pools during* 1941

County, Field and Location	Operator and Fee	Geologic Formation	Depth, Ft.	Month	Initial Production, Bbl.
Barber County					
Lake City, 18-31-13W	Pryor & Lockhart No. 2 "C" Gant	Simpson	4,530–4,541	Nov.	153
Barton County					
Ainsworth NW., 29-16-13W	Continental No. 1 Harrington	Lans. K. C.	3,140–3,150	Nov.	366
Davidson, 4-16-11W	Blair No. 1 Peirano	Lans. K. C.	3,016–3,020	Apr.	243
Eberhardt, 24-19-11W	Vickers No. 1 "C" Heer	Lans. K. C.	3,094–3,105	Oct.	2,790
Rick, 11-19-11W	Shell No. 1 Rader	Lans. K. C.	3,106–3,120	July	3,000
Straub, 36-18-11W	Lauck & Moncreif No. 1 Dutton	Lans. K. C.	3,122–3,132	June	675
Butler County					
Keighley, 23-27-7E	Phillips No. 25 Keighley	Hunton	3,148–3,158	May	297
Phillips County					
Ray, 28-5-20W	Cities Service No. 1 Vehege	Arbuckle	3,568–3,579	July	2,572
Rice County					
Bowman, 21-19-10W	Sharon Drill No. 1 Nevius	Lans. K. C.	3,032–3,042	June	466
Geneseo, 31-18-7W	Continental No. 4 Powell	Simpson	3,186–3,190	Mar.	149
Russell County					
Dubuque, 27-15-12W	Mackall No. 1 "B" Klusner	Lans. K. C.	3,153–3,196	Aug.	290
Rusch, 29-14-14	Westgate Greenland No. 2 Rusch	Lans. K. C.	3,071–3,084	July	50
Stafford County					
Schaeffer, 4-21-13W	Texon No. 1 Shaeffer	Arbuckle	3,546–3,558	Nov.	400
Stafford, 15-24-12W	Stanolind No. 1 "B" Charles	Arbuckle	3,945–3,955	Mar.	1,098

believe to be part of a stratigraphic trap similar to and probably connecting with the Zenith pool of southeastern Stafford County. Because of the large production from the Zenith pool, it is believed that the three new pools will open up the largest reserve discovered during the year. A similar situation exists in southeastern Rice County, where two new pools, the Welch East and the Bornholdt West, give indications of uncovering a large reserve. There also the production is coming from a stratigraphic trap which in all probability is the same as that now producing in the near-by Welch and Bornholdt pools.* The new pool in Norton County, the Hewitt, extends the productive limits of Kansas oil areas to the northwest and may have far-reaching implications. The Ray Southeast pool in northwestern Rooks County appears to be on the same structure that yields the oil in the Ray pool of Phillips County. Oil was found in a basal arkosic material which may be pre-Cambrian in age. The Reagan sand which produces in the Ray pool was apparently absent in the discovery well (No. 1 Steele).

Drilling Activity

The areas that received most attention during the year were the large fields in Russell and Barton Counties. The very interesting Hall-Gurney pool was extended in a number of directions and promises to merge with other near-by pools during the coming year. No less than 117 wells were drilled in this field of which only 7 were failures. In the important Trapp pool, of southern Russell County, 96 wells were completed, of which 84 were oil wells. In southeastern Barton County the large Silica pool was extended in several directions. Of 95 wells drilled there, 76 were successful. In the Ray pool, of Phillips County, one of the most promising pools found in 1940, an additional 32 wells were completed. One of these found production in the Arbuckle dolomite, thus opening a new producing horizon for that field. In eastern Kansas, the McLouth pool proved to be the important area. Here 33 new gas wells were brought in and 7 oil wells. In the McLouth pool there are three producing zones, one in the lower Pennsylvanian system and two in the Mississippian system. Most of the gas is derived from a sandstone at the base of the Pennsylvanian strata, and some oil is also obtained at the same level. A small portion of the gas comes from the weathered and eroded top portion of the Mississippian. Up to date this zone has not furnished any oil wells, although good shows have been found. The third producing zone lies well within the Mississippian limestone sequence, at a depth of 135 ft. below the top of the system. It produces oil. The production in the Pennsylvanian sandstone appears to be related to differential porosity and permeability, while the oil in the Missisipian seems to be rather closely related to structural conditions.

Exploration

The year 1941 undoubtedly will prove to be one of the most interesting from the standpoint of exploration for new supplies of oil. A determined and ambitious attempt was made by both major companies and independents to find new reserves. In Barber County, the drilling campaign was quite successful, as two new pools were found and a new producing horizon in another. In Graham County, on the northwestern fringe of the oil region, 10 exploratory wells were drilled and these were scattered over the County. One of these opened a new pool, but the others were dry. In southeastern Kingman County, one promising outpost well was a failure. In Ness County, another promising test, also well located, proved to be dry.

In Norton County the search for new pools was perhaps more intensive than in any other county. Here the possibility of finding oil in stratigraphic traps was great. Furthermore, the successful drilling campaign in Phillips and in Graham Counties held out considerable promise of similar conditions in Norton County. Also, it will be remembered that one very good showing had been found here the previous year in the Van Patten pool (later abandoned). No less than 10 exploratory wells were completed in Norton County during 1941 but of these only one was successful in finding new oil reserves.

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* A chart of producing horizons of western and southern Kansas is shown on page 291 of volume 136, *Trans.* A.I.M.E. (1940).

In Pawnee County, where rather large wells were brought in to extend the Pawnee Rock pool, wildcatting was carried on over a wide area. The six scattered test wells were all dry holes. However, to offset this poor showing, a rather long extension to the Pawnee Rock pool was uncovered in western Barton County, which adjoins Pawnee on the east. Temporarily this is classified as the Pawnee Rock East pool. In Phillips County, one of the most northerly outposts of the oil region, the success of drilling in the Ray pool encouraged widespread wildcatting. One new pool was uncovered, but the remaining tests, drilled on good geological prospects, were all dry. Drilling in Pratt County was stimulated by the large production obtained from the Viola limestone in the Cairo pool. Eleven test wells drilled in this area were completed during the year. Two of these opened new gas pools of doubtful value and the rest were failures. In Rooks County, the favorable results of drilling in the Laton pool encouraged wildcatters to start seven test wells. One of these, several miles southeast of the Ray pool (in the adjoining Phillips County), was successful in finding a new oil pool (Ray Southeast). Another test well, in the southeastern part of the county, was also successful in opening an oil pool (Erway pool). The remaining holes were dry. In Rush County three dry holes were drilled. In Sedgewick County two rank wildcat wells were completed during the year, but both were failures.

This record clearly indicates that oil is becoming more elusive, for virtually all the test wells cited were drilled after exhaustive preliminary surveys had been made. Many wells were located on geophysical prospects, which had been corroborated by careful subsurface studies; for others the exploratory work included core-drill tests and other methods of obtaining information.

ACKNOWLEDGMENTS

The author would have been unable to prepare this report without the generous help of many individuals. Among those who supplied the greatest amount of information are Theo Morgan, the Director of the State Corporation Commission; J. H. Page, gas expert for the State Corporation Commission; Zenas Stucky, Anthony Folger, George F. Berry, Harold Smedley, Edward Koester, and Raymond A. Whortan.

Oil and Gas Development in Kentucky during 1941

By George Straughan* and Ralph Thomas†

Oil production in Kentucky in 1941 was 5,191,024 bbl., one barrel less than in the preceding year.

The total completions for the state numbered 714, of which 256 were gas producers, 220 oil wells, and 227 dry holes. The total number was 95 more than in 1940. No new important oil or gas pools were discovered. The number of dry tests was large, although many of the dry holes could be considered wildcat tests.

In western Kentucky, 365 wells were drilled, of which 145 were oil producers,

Table 1.—*Drilling Operations in Kentucky during* 1941

County	Number Wells Completed	Dry and Abandoned	Producing Wells		Initial Production		Deepest Horizon Tested	Wells Drilling 12/31/41
			Gas	Oil	Oil, Bbl.	Gas		
Western Kentucky								
Breckenridge	4	4					McClosky	
Butler	8	2		6	61		Jones	
Christian	2	2					Corniferous	
Clay	6	1	5			y	Corniferous	
Clinton	12	3	3	6	105	y	Granville	
Cumberland	8	2		6	55		Granville	
Daviess	93	41	2	43	2,020	y	McClosky	
Graves	2	2					St. Peter	
Grayson	2	2					St. Peter	
Hancock	27	15		12	87		McClosky	
Henderson	42	19		23	447		McClosky	
Jackson	5	1	4			y	Corniferous	
Knox	4		4			y	Corniferous	
Lewis	2	2					Corniferous	
Logan	1	1					Jackson	
McLean	33	21		12	1,802		McClosky	
Muhlenberg	10	7	2			y	McClosky	
Ohio	75	44	3	28	507	y	McClosky	
Pulaski	4	4					Corniferous	
Union	11	7		4	363		McClosky	
Wayne	6	3		3	18		Upper Sunnybrook	
Webster	5	3		2	35		McClosky	
Totals	365	186	23	145	6,002	y		
Eastern Kentucky								
Carter	1	1					Corniferous	
Elliott	3	1	1	1	10	y	Knox	1
Estill	48	5	0	43	442	0	Corniferous	
Floyd	71	6	65	1	20	y	Corniferous	15
Greenup	2			2	6		Berea	
Johnson	16	2	14			y	Corniferous	6
Knott	47	2	45			y	Devonian shale	14
Lee	17	1	0	16	76	0	Corniferous	
Magoffin	2	1	1			y	Knox	
Martin	42	4	32	6	122	y	Clinton	11
Morgan	3	3					Corniferous	
Pike	81	9	72			y	Devonian shale	36
Powell	16	6	4	6	49	y	Corniferous	
Totals	349	41	233	75	725	y		83

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23 gas wells, 4 stratigraphic tests, 9 key wells and 186 dry or abandoned. The 186 oil wells had an initial production of approximately 6002 barrels.

In eastern Kentucky, 359 wells were completed during the year, of which 233 were gas producers, 75 oil wells, 41 dry or abandoned. The Big Sinking oil field of Estill, Lee and Powell Counties accounted for 65 of the producing oil wells.

During 1941, four deep tests were completed in eastern Kentucky. In Magoffin County, on the Paint Creek Uplift; the Cumberland Petroleum Co. deepened an old Corniferous well to the Knox dolomite to a total depth of 5080 ft. A sandy limestone was encountered in the St. Peter horizon, but the true sand was absent. No commercial oil or gas was encountered. In Elliott County, on the Burke dome, the Inland Gas Co. completed a test to the Knox dolomite at a total depth of 4192 ft. According to Mrs. Louise Freeman, of the State Department, approximately 65 ft. of fine sand was encountered in the St. Peter horizon. This sand made salt water, but no commercial oil or gas was found. In Clark County, in the Ruckerville fault area, W. O. Allen drilled a test to the Knox dolomite to a total depth of 2020 ft. A sand was penetrated at the approximate St. Peter horizon, but according to the State Department it could not be called St. Peter, its presence being due to an unconformity present at the top of the Knox. No commercial oil or gas was present. In Laurel County, on the Sinking Creek dome, the Globe Oil and Gas Co. completed a well in the Knox dolomite at a total depth of 3800 ft.; no sand was present in the St. Peter horizon in this test and no commercial oil or gas was encountered.

The widely publicized leasing activity in the eastern part of the state was pursued by major oil companies and all acreage on known and mapped structures has been acquired.

Drilling activity has been curtailed to a certain extent by most operating companies in eastern Kentucky until some modification of the Office of Production Management's Conservation Order M-68 is obtained, allowing them to resume normal operations.

Table 1 shows by counties the new development in Kentucky during 1941. This information was compiled from all available sources and reflects a careful check of individual wells; should not be much in error, unless there has been a failure to report certain wells.

GAS

Floyd County.—The 65 gas wells produced from the following formations:

Number of Wells	Formation	Combined Open Flow
2	Salt sand (Pen.)............	*y*
3	Maxon (Mis.)............	*y*
11	Big Lime (Mis.)............	*y*
49	Shale (Dev.)............	*y*
	Total............	*y*

The drilling in this county was in proven territory.

Johnson County.—The 14 wells produced from the following formations:

Number of Wells	Formation	Combined Open Flow
4	Shale (Dev.)............	*y*
10	Big Six (Sil.)............	*y*
	Total............	*y*

The Big Six sand production represents the discovery of a new field 4 miles west of Paintsville.

Knott County.—The 45 wells produced gas from the following formations:

Number of Wells	Formation	Combined Open Flow
0	Salt sand (Pen.).	
4	Maxon (Mis.)............	*y*
3	Big Lime (Mis.)............	*y*
38	Shale (Dev.)............	*y*
	Total............	*y*

The larger portion of this development represents wells in proven territory but there were some extensions to known fields.

Magoffin County.—In former years in this County approximately 1200 wells had been drilled for oil. Of this number 900 were Weir sand oil wells and 100 were dry holes.

In the extreme southern part of the county is the Fych gas field in which there are 53 wells producing from the Salt sand, Maxon, Big Lime, Injun and shale formations. One gas well was completed during 1941 with an open flow of 298,000 cu. ft. daily from the Devonian shale and Big Injun horizons.

During 1941 the Cumberland Petroleum Co. deepened an old Corniferous well to the Knox dolomite to a total depth of 5080 ft. No commercial oil or gas was encountered.

Martin County.—The 32 gas wells produced from the following formations:

Number of Wells	Formation	Combined Open Flow
2	Salt sand (Pen.)	*y*
4	Maxon (Mis.)	*y*
1	Big Lime (Mis.)	*y*
25	Shale (Dev.)	*y*
	Total	*y*

Pike County.—The 72 gas wells produced from the following formations:

Number of Wells	Formation	Open Flow Combined
11	Salt sand (Pen.)	*y*
14	Maxon (Mis.)	*y*
2	Big Lime (Mis.)	*y*
45	Shale (Dev.)	*y*
	Total	*y*

Part of this production was from proven areas, but this county had more new development than any other county in the Big Sandy area.

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Petroleum Development and Production in Louisiana during 1941

By J. Huner, Jr.*

Louisiana ranks fifth among the oil-producing states. In 1941 the state-wide production was slightly in excess of 118,000,000 bbl. of crude oil and condensate—an increase of 15,000,000 bbl. over the total production for the year 1940.

During 1941, south Louisiana produced approximately 90,900,000 bbl. of oil, while north Louisiana produced approximately 27,000,000. South Louisiana, therefore, produced about 3¼ times more oil than north Louisiana.

During the past year, 574,800,000 M cu. ft. of natural and casinghead gas were produced in Louisiana; thus 1941 gas production exceeded the 1940 production by 104,900,000 M cu. feet.

Completion records for the year 1941 show that 1512 wells were completed in or adjoining producing fields. These wells, which were drilled to extend known producing areas or were located within producing areas, are not considered as wildcat wells. Of the total number of field wells drilled, 1152 wells found production; the remaining 360 were junked or dry and abandoned. This means that 76 per cent of the wells drilled were successful. Considering the precarious nature of oil-field development, this percentage of new producing wells is exceedingly satisfactory.

Of the total number of field wells completed as producers, approximately 86 wells found new and distinct producing sands.

During the past year, 30 new fields were found. Four parishes—namely, Caldwell, Catahoula, Orleans, and Natchitoches—entered the ranks of oil-and-gas-producing parishes in the state during that period. This brings the total number of oil-and-gas-producing parishes in the state up to 48. Thus, 75 per cent of the parishes in Louisiana now contain one or more oil and/or gas fields.

Although sufficient data are not available to list the addition reserves found in Louisiana during 1941, it is felt that such reserves undoubtedly exceed twice the total production for that year, or at least 200 million barrels. In reserves, therefore, Louisiana ranks third among the various oil-producing states.

South Louisiana

Although 16 new fields were found in south Louisiana, the outstanding developments in that part of the state were not limited to new discoveries. In fact, most of the increase in reserve in that area has been most consistently accumulated through extensions of known producing sands and through the finding of new sands in already productive fields, especially at depths below the presently producing sands. Since data concerning most of the new extensions and sands are too extensive for discussion here, the more important developments are briefly outlined below:

Abbeville, Vermilion Parish.—Production extended ½ mile to the west.

Anse La Butte, St. Martin Parish.—New oil sand discovered at 9400 ft., thus extending production to east flank. West flank defined by dry holes.

Barataria, Jefferson Parish.—New oil sand discovered on east side of field at 7620 ft. New

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distillate sand found at 10,054 ft. on south flank. East flank defined by dry hole.

Bateman Lake, St. Mary Parish.—Production extended ½ mile on east and west flanks. Present production defined by dry hole on south flank.

Bayou Bleu, Iberville Parish.—Production extended 4800 ft. on east flank and 2100 ft. on north flank. Present production defined by dry hole on southwest flank.

Bayou Bouillon, St. Martin Parish.—Production extended 8500 ft. on south flank and also limited on south flank by dry hole.

Bayou Choctaw, Iberville Parish.—Production extended 1100 ft. on east flank.

Bayou des Allemands, St. Charles Parish.—Production extended 1000 ft. on west flank.

Bayou des Glaises, Iberville Parish.—Present production defined on north and south flanks.

Bayou Pigeon, Iberia Parish.—Production extended 1000 ft. on southeast flank and defined by dry hole on northwest flank.

Bayou Sale, St. Mary Parish.—Discovery sand found at 10,100 ft. New oil sand discovered at 10,300 ft., extending field 6000 ft. toward the south. Slight extension on north flank and dry hole defining the east flank.

Bay St. Elaine, Terrebonne Parish.—Production extended 1250 ft. west on southwest flank.

Caillou Island, Terrebonne Parish.—Present production defined on south flank.

Cameron Meadows, Cameron Parish.—New oil sands found at 1300 ft. and 5700 feet.

Chacahoula, Lafourche Parish.—Present production defined on northwest flank.

Chalkley, Cameron Parish.—Production extended ½ mile on south and southeast flanks, and defined on west flank.

Delacroix Island, Plaquemines Parish.—First oil sand found at 8965 ft., slightly deeper than discovery of gas-condensate sand at 8915 feet.

Delta Duck Club, Plaquemines Parish.—Discovery sand found at 11,400 ft. New sand found at 9580 ft., 1600 ft. west of the discovery well.

Delta Farms, Lafourche Parish.—New oil sand found at 8770 ft. on east flank. Production extended 1500 ft. on northeast flank.

Dog Lake, Terrebonne Parish.—Present production defined on northwest and southeast flanks.

East White Lake, Vermilion Parish.—New oil sands found at 6400 ft., 7300 ft. and 9800 ft. Field extended 1½ mile toward the northeast.

Edgerly, Calcasieu Parish.—New oil sand found on southeast flank at 6900 ft. Present production also defined on southeast flank.

Erath, Vermilion Parish.—Sand of low gas-oil ratio found at 8700 ft. New condensate sands found at 11,378 ft. and 11,618 ft. Production extended on the west flank and defined on southwest flank. Previous production also extended ½ mile toward the south.

East Hackberry, Cameron Parish.—New oil sand found at 10,000 ft. on north flank.

Fausse Pointe, Iberia Parish.—Present production defined in southwest flank. New oil sand at 8700 ft. on north flank.

Gibson, Terrebonne Parish.—Production extended one mile to the northeast and defined on southwest flank.

Garden Island Bay, Plaquemines Parish.—Production gradually being extended around the southeast flank toward the south.

Golden Meadow, Lafourche Parish.—The 5100-ft. and 5400-ft. oil sands extended 800 ft. east of Bayou Lafourche.

Gueydan, Vermilion Parish.—New oil sands found at 4800 ft., 7500 ft., 8750 ft., 9720 ft. and 9760 ft. Production subsequently extended 1500 ft. toward the west and 1000 ft. to the southeast.

Iowa, Calcasieu Parish.—New oil sand discovered 6970 ft. on west flank. The 7600-ft. sand extended slightly toward the north, while the 8200-ft. sand was extended to the north and northeast and defined on the west.

Jefferson Island, Iberia Parish.—New oil sands discovered at 3070 ft. on southwest flank and 8080 ft. on south flank. Production extended 4150 ft. west of previous production.

Kenilworth, St. Bernard Parish.—New condensate sand found at 10,300 ft., extending production 1800 ft. toward the east.

Lake Arthur, Jefferson Davis Parish.—Two condensate sands found on north flank at 8500 ft. Production defined on northeast flank.

Lake Hermitage, Plaquemines Parish.—Present production limited on southwest flank.

Lake Long, Lafourche Parish.—Production extended 1500 ft. on northeast flank.

Lake Chicot, St. Mary Parish.—Discovery sand found at 9025 ft. New oil sand found at 8150 ft., 1000 ft. northeast of discovery well.

Lake Pelto, Terrebonne Parish.—Present production limited on northwest flank.

Lake Salvador, St. Charles Parish.—Production on east and south flanks extended 1300 feet.

Lakeside, Cameron Parish.—Discovery sand found at 9972 ft. New condensate sand found at 9900 ft., approximately 3200 ft. east of discovery well.

La Pice, St. James Parish.—Present production defined on northeast flank.

Lockport, Calcasieu Parish.—Present production defined on northeast flank.

Pecan Lake, Cameron Parish.—Discovery sand found at 10,174 ft. and extended 3000 ft. toward the southeast.

Port Allen, West Baton Rogue Parish.—Production extended.

Port Barre, St. Landry Parish.—New oil sands found at 5650 ft. on north flank and at 6638 ft. on southwest flank.

Potash, Plaquemines Parish.—New oil sands found at 8450 ft. and 8688 ft. on southwest flank.

Section "28," St. Martin Parish.—First oil sand found at 10,854 ft. on northwest flank. New condensate sands also found at 8900 ft. and 10,000 ft. Production limited on north and west flanks.

Raceland, Lafourche Parish.—Present production limited on southeast flank.

St. Gabriel, Iberville Parish.—Discovery sand found at 7773 ft. New oil sand found at 8634 feet.

Starks, Calcasieu Parish.—Present production defined on northwest flank.

Stella, Plaquemines Parish.—New oil sands found at 7000 and 7500 ft., latter sand extending production 2000 ft. toward the east.

South Crowley, Acadia Parish.—Present production defined on south and southeast flanks.

University, East Baton Rouge Parish.—New oil sand found at 9500 ft. on south flank.

Venice, Plaquemines Parish.—New oil sand found at 10,600 ft. on northwest flank.

Vacherie, St. James Parish.—Present production defined on south flank.

Vinton, Calcasieu Parish.—New oil sand found at 3600 ft., one mile southwest of production. Present production defined on southeast and southwest flanks.

Welsh, Jefferson Davis Parish.—New gas sand found at 5278 ft. and new oil sands at 6534 and 7330 feet.

West Bay, Plaquemines Parish.—New oil sands found at 6264 ft. and 6836 feet.

West Cote Blanche, St. Mary Parish.—New oil sand found at 7640 ft., approximately 1300 ft. north of production.

West Hackberry, Cameron Parish.—New oil sand found on northeast flank at 9700 ft. Present production limited on southeast flank.

West Lake Verret, St. Martin Parish.—New oil sand found at 2300 ft. Present production limited on southeast flank. Production extended 2000 ft. toward the south.

West Mermentau, Jefferson Davis Parish.—New condensate sand found at 9100 feet.

Woodlawn, Jefferson Davis Parish.—Production extended ½ mile on east flank and defined on southeast flank.

NORTH LOUISIANA

In north Louisiana, the chief interest of the industry during 1941 was focused on the so-called "Wilcox trend." More particularly, it was concerned with producing sands found approximately 700 to 1600 ft. below the top of the Wilcox. That this interest was not misguided is indicated by the fact that 10 new fields productive from below the top of the Wilcox were found in the trend during 1941.

Structure maps contoured on top of the Wilcox over fields productive from the Wilcox in the southern part of the trend show considerable closure. The Neale field, in Beauregard Parish, which is a fault-line field, is an exception and shows relatively little closure on top of the Wilcox. In the northern part of the trend—that is, the La Salle Parish area—contour maps on top of the Wilcox over fields producing from the Wilcox show almost no closure. The closure does, however, become more pronounced with depth. The latter is caused chiefly by a thinning of the Wilcox over the structure, rather than by any increased structural distortion of the beds.

To account for the accumulation of petroleum in various fields in the northern part of the trend poses a difficult problem. In some fields, faulting has been chiefly responsible; in other fields, stratigraphic trapping is dubiously suggested. However, because some petroleum-bearing sands—for example, the Cruse sand, named from the Olla field—can be traced downdip through many of the fields in La Salle Parish, stratigraphic trapping does not appear to be an entirely plausible explanation in all fields.

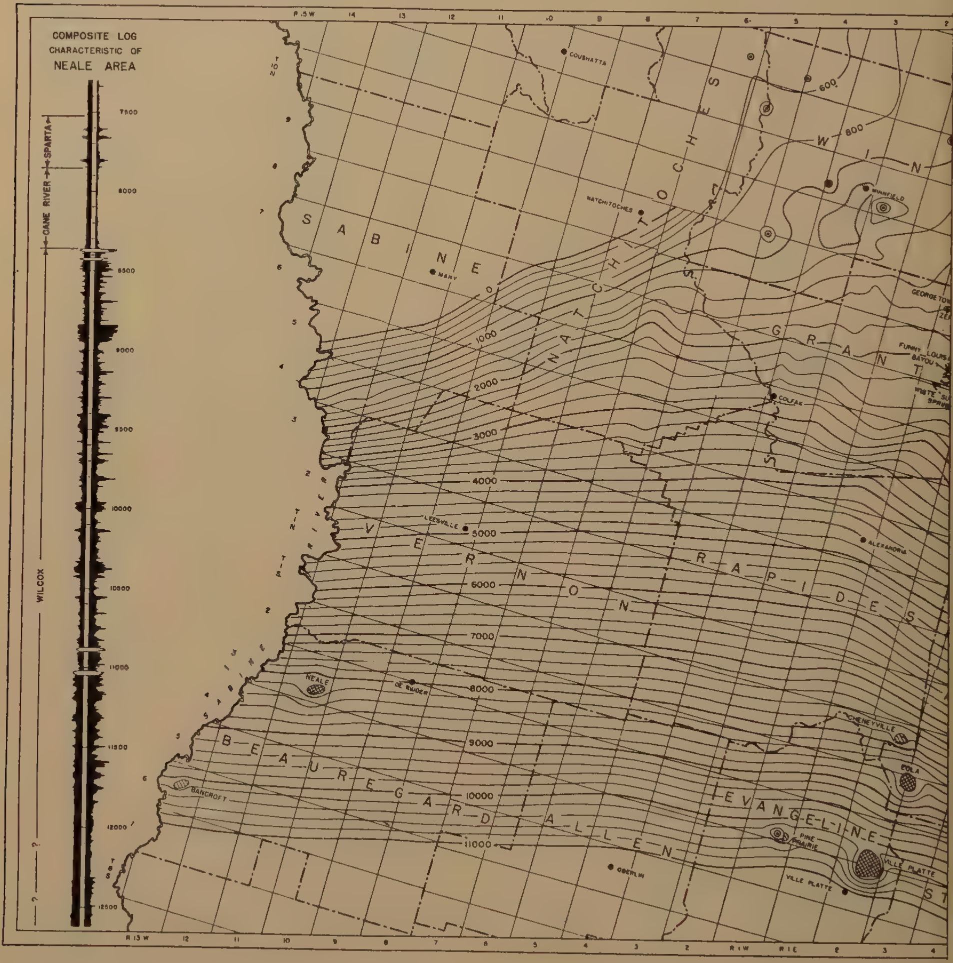


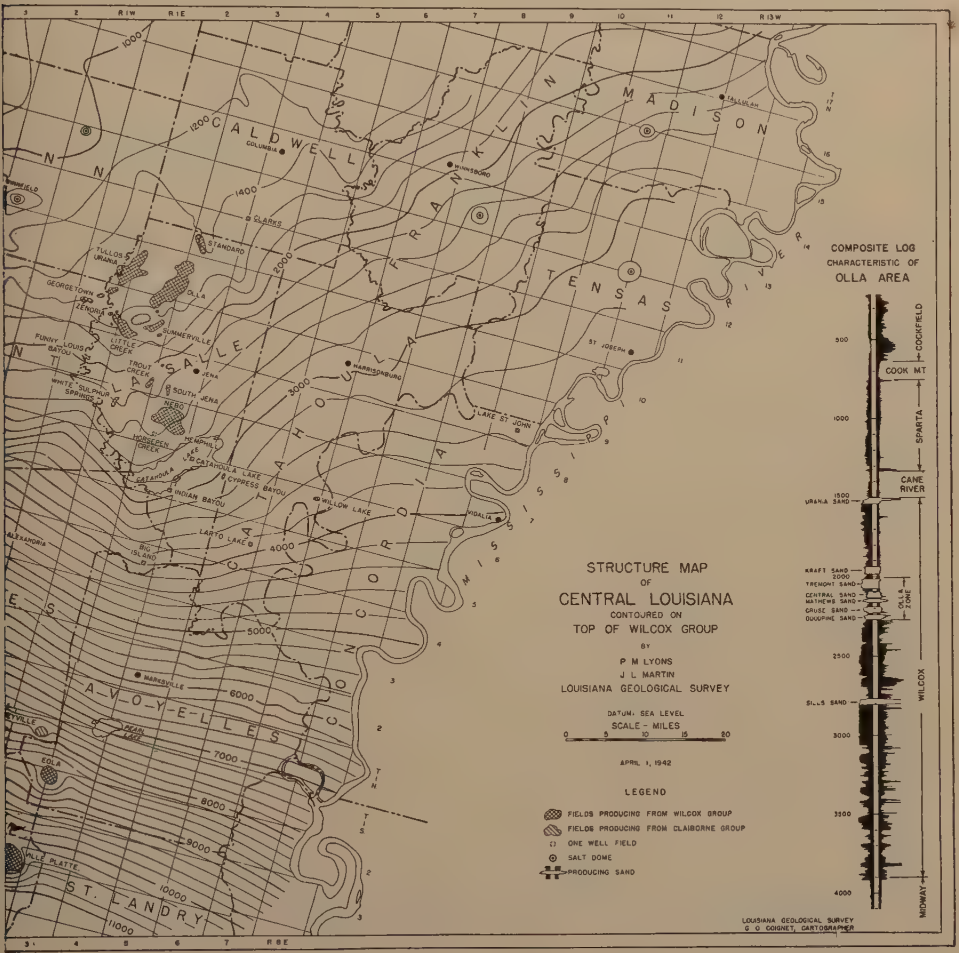
FIG.

Correlation of sands and other sedimentary units is fairly satisfactory in the central and southern parts of the Wilcox trend. However, in the northern part, correlations are exceedingly difficult because of the lenticularity of the various sands and shales. The interpretation of electrical logs in this part of the trend is also difficult. The logs do not always reflect the sand content and are even erroneous to the extent of being misleading. As a matter of fact, the only satisfactory method of determining whether or not a Wilcox sand contains any liquid or gaseous hydrocarbons is to core it.

Aside from the new Wilcox field discoveries, those Wilcox fields found prior to 1941 have had extensive development during the past year.

Developments in Old Fields

The *Olla field*, in La Salle Parish, was defined and now covers approximately 8300 acres. It is the largest field in the Wilcox trend. During 1941, two new oil sands—namely, the Tremont (1900 ft.) and the Kraft (1900 ft.)—and one new gas sand, the Sills (2630 ft.), were found in this field.



1.

The *Nebo field*, discovered in 1940, was extended considerably during 1941, especially toward the south, southwest and east. The field was defined on all sides except on the south. Although sufficient data are not available, it seems likely that the deeper sands in the Nebo field will be continuous and extend into the Hemphill field, about 2 miles south. Totaled, 10 new sands, all within the so-called "Nebo zone" (3300 to 4200 ft.), were found in the field during 1941.

The *Summerville field*, discovered in 1940, has had eight completions during 1941, all of which were oil wells. During this same period, a number of dry holes were also drilled. Since the field is appar-

TABLE 1.—*Oil and Gas Production in Louisiana*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
	A. SOUTH LOUISIANA													
1	Abberville, *Vermilion*	1937	200		644,199	123,023	6,078	2,686	9	2		1	4	6
2	Anse La Butte, *St. Martin*	1902	200		2,743,627	1,525,622	761	656	*y*	40	*y*	2	55	0
3	Bancroft, *Beauregard*	1938	750		2,788,333	838,624	13,763	3,997	43	0	*y*	5	32	3[2]
4	Barataria, *Jefferson*	1939	250		1,451,667	1,003,539	796	608	22	12	0	0	21	1
5	Bastian Bay, *Plaquemines*	1941	80		11,461	11,461	3	3	2	2	0	0	2	0
6	Bateman Lake, *St. Mary*		3,700		920,306	213,961	720	189	12	4	0	0	4	8[2]
7	Bay Baptiste, *Terrebonne*	1938	Abandoned		1,320	0	68	0	1	0	0	0	0	0
8	Bayou Blue, *Iberville*	1929	120		900,869	630,519	154	95	38	19	*y*	1	29	1[2]
9	Bayou Bouillon, St. *Martin*	1902	40		410,458	6,680	102	102	*y*	1	1	*y*	1	2
10	Bayou Choctaw, *W. Baton Rogue and Iberville*	1931	300		3,572,222	503,674	376	115	25	3	4	5	17	*y*
11	Bayou Des Allemands, *St. Charles and Lafourche*	1937	240		382,699	132,596	1,202	599	9	2		2	6	0
12	Bayou Des Glaises, *Iberville*	1940	50		4,811	415	*y*	*y*	1	0		0	1	0
13	Bayou Mallet, *Acadia*	1936	360		427,308	90,345	1,015	360	8	0	0		3	2
14	Bayou Pigeon, *Iberia*	1940	100		370.905	272,276	147	86	5	2	0	0	5	0
15	Bayou Sale, *St. Mary*	1941	1,000		141,750	141,750	87	87	8	8	0	0	8	0
16	Bay St. Elaine, *Terrebonne*	1934	180		662,346	245,400	440	198	14	5	*y*	3	9	0
17	Belle Isle, *St. Mary*	1941		100	1,861[1]	1,861[1]	154	154	1	1	0	0	1	0
18	Big Lake, *Cameron*	1935	Abandoned		72,338	0	263	0	0	0	0	0	0	0
19	Black Bayou, *Cameron*	1929	275		8,715,269	863,829	1,322	0	25	4	*y*	7	22	0
20	Bosco, (includes Cankton) *Acadia and St. Landry*	1934	1,600	640	21,956,667	1,506,621	67,870	6,275	72	0	1	0	42	3 9[2]
21	Caillou Island, *Terrebonne*	1930	600		32,194,586	1,999,563	2,006	1,050	59	2	*y*	0	49	0
22	Cameron Meadows, *Cameron*	1931	300		8,462,286	825,191	763	144	66	7	*y*	6	37	0
23	Chacahoula	1938	200		1,352,676	488,468	85	620	12	5	0	1	11	1
24	Chalkley, *Cameron*	1938	1,500		2,860,372	1,681,216	6,724	3,329	35	15	*y*	2	29	3[2]
25	Charenton, *St. Mary*	1936	750		8,412,923	1,852,355	3,046	300	203	11	1	2	161	*y*
26	Cheneyville, *Rapides*	1935	640		2,796,982	1,055,273	10,005	2,237	49	5	0	1	31	2
27	China, *Jefferson Davis*	1940	80		7,110[1]	3,532[1]	822	456	1	0	0	0	0	1[2]
28	Creole, *Cameron*	1938	100		1,706,485	395,092	686	243	10	0	0	2	8	0
29	Darrow, *Ascension*	1932	175		4,969,233	673,680	2,117	307	22	2	*y*	*y*	20	0
30	Delacroix Island, *Plaquemines*	1941	120		7,364[1]	7,364[1]	80	80	2	2		0	1	1[2]
31	De Large, *Terrebonne*	1938		640	154,610[1]	46,884[1]	5,331	1,600	1	0	0	0	0	1
32	Delta Duck Club, *Plaquemines*	1941	120		33,827	33,827	44	44	2	2	0	0	2	0

[b] Footnotes to columns heads and explanation of symbols are given on page 250.

[1] Condensate production only .

[2] Gas wells shut in.

TABLE 1.—(*Continued*)

Line Number	Oil-Production Methods, End of 1941		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells													
	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Range of Producing Sands	Number of Sands	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
A. SOUTH LOUISIANA														
1	4	0	50	0.1		MioU	S	26	6,400–10,300	5	20	D	Urigerina	12,214
2	53	2	23			Pli	S	Por	1,165– 2,400	2	20	DS	L. Miocene	9,875
			37.7			MioU	S	30	2,800– 6,000	7	70	DS		
			32.4			MioL	S	25	9,430– 9,465	1		DS		
3	17	15	43		Cockfield	Eoc	S	*y*	7,250– 7,452	2		AF	Wilcox	11,018
4	21	0	37	0.2		MioU	S	32	7,600–10,000	4	20	D	U. Miocene	12,246
5	2	0	35.6			MioU	S	Por	9,350	1	28	D	U. Miocene	10,714
6	4	0	43			MioU	S	Por	8,600–10,900	5	25	D	U. Miocene	11,876
7	0	0	49.6			MioU	S	Por	11,200	1		D	U. Miocene	13,409
8	25	4	32			MioU	S	Por	1,250– 6,530	14	28	DS	L. Miocene	11,049
9	0	1	20.0			MioU	S	27	3,200	1	15	DS	L. Miocene	9,405
						MioL	S	Por	7,480	1	15	DS		
10	17	0	26			MioU	S	27	2,400– 6,300	13	25	DS	L. Miocene	10,033
			37			MioL	S	38	7,500– 8,400	4	25	DS		
11	6	0	35	0.2		MioU	S	Por	6,800– 9,400	2	30	DS	U. Miocene	10,696
12	1	0	37.8	0.13		MioL	S	Por	8,640	1	7	DS	Miocene	10,380
13	3	0	30			MioL	S	Por	6,380– 7,190	3		D	Vicksburg	8,404
14	3	2	27			MioL	S	30	8,050– 8,150	2	10	D	U. Miocene	10,000
15	8	0	35			MioU	S	30	10,100–10,300	2	70	D	U. Miocene	11,877
16	8	1	29			MioU	S	Por	5,600– 9,300	5	40	DS	U. Miocene	11,012
17	1	0	47.1			MioU	S	Por	9,800	1	55	DS	U. Miocene	11,117
18	0	0	39			MioU	S	Por	6,700– 7,800	2	20	D	Marginulina	10,521
			38			MioL	S	Por	8,300– 9,050	2	20	D		
19	14	8	23	0.15		MioU	S	35	4,200– 5,500	7	35	DS	L. Miocene	8,480
			40			MioL	S	35	7,500	1		DS		
20	42[3]		38			MioL	S LS	Por	7,900– 8,825	7	27	D	Vicksburg	10,434
21	46	6	35			MioU	S	Por	3,700– 7,800	20	67	DS	U. Miocene	9,350
22	10	27	20			Pli	S	Por	1,300	1	30	DS	Salt	9,331
			30			MioU	S	Por	3,300– 5,600	5	30	DS		
23	11	0	34			MioU	S	30	6,034– 9,341	6	50	DS	L. Miocene	13,004
24	29	0	36			MioU	S	Por	7,100– 8,900	4	32	D	L. Miocene	11,693
			37			MioL	S	Por	8,400–10,100	3	30	D		
25	68	93	22			MioU	S	Por	950– 6,500	9	20	D	U.Miocene	10,690
26	25	6	44		Cockfield	Eoc	S	Por	5,350– 5,500	3	28	DS	Wilcox	8,230
			44		Sparta	Eoc	S	Por	6,150	1	10	DS		
27	0	0	20			MioL	S	Por	9,300	1	20	D	L. Miocene	9,530
28	8	0	34			MioU	S	Por	5,200– 6,600	3	25	D	U. Miocene	9,895
29	20	0	30	0.12		MioU	S	Por	4,250– 7,000	6	45	DS	L. Miocene	10,013
			29.5			MioL	S	Por	8,260	1	27	DS		
30	1	0	45			MioU	S	*y*	8,900– 8,950	2	18	D	U. Miocene	11,165
31	1	0	50.8			MioU	S	Por	13,000	1		D	U.Miocene	13,333
32	2	0	42.5			MioU	S	25	10,750– 1,110	2	22	D	U. Miocene	11,494

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[3] Pressure maintenance from early life of field.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
33	Delta Farms, *Lafourche and Jefferson*	1940	320		182,221	152,429	538	531	2	2	0	0	1	3
34	Dog Lake, *Terrebonne*	1935	160		2,451,325	465,386	767	113	17	3	y	1	10	3[2]
35	East Hackberry, *Cameron*...........	1927	560		28,377,658	1,619,851	4,039	972	66	9	y	3	61	1
36	East White Lake, *Vermilion*.............	1940	640		81,006	81,006	584	462	4	3	0	1	3	0
37	Edgerly, *Calcasieu*	1912	215		8,416,142	119,904	2	2	177	1	y	1	17	y
38	*Eola, Aroyelles*.......	1939	2,100		8,597,616	3,671,344	11,095	5,792	101	6	y	0	94	0
39	*Erath, Vermilion*.....	1940	2,280		184,728	174,204	844	778	9	7	0	0	7	2[2]
40	Fausse Point, *Iberia and St. Martin*.....	1926	100		113,079	43,567	294	108	y	1	y	0	4	1 1[2]
41	Four Isle Bay, *Terrebonne*..............	1935	Abandoned		102,512	0	0	0	y	0	0	0	0	0
42	Garden Island Bay, *Plaquemines*........	1935	350		4,726,077	1,229,211	865	230	40	6	4	5	30	0
43	Gibson, (inc. N.E. Gibson) *Terrebonne*	1937	350		5,253,093	1,406,347	4,059	631	23	5	0	1	21	1
44	Gillis-English Bayou, *Calcasieu*..........	1934	1,200		20,201,606	1,304,868	29,314	5,627	120	6	y	11	42	4
45	Golden Meadow, *Lafourche*............	1938	1,400		9,672,902	4,821,015	3,378	1,724	207	46	y	18	190	1
46	Grand Bay, *Plaquemines*..............	1938	1,000		3,800,960	2,055,944	2,796	2,061	32	11	0	1	31	0
47	Grand Lake, *Cameron*	1939	600		3,208,289	1,641,322	2,265	1,456	24	1		1	22	1[2]
48	Gueydan, *Vermilion*..	1932	100		1,749,097	583,995	822	641	21	10	y	1	14	1
49	Hackberry Bay, *Jefferson*..............	1941		160	0	0	y	y	1	1	0	0	0	0
50	Happytown, *St. Martin*................	1939	80		296,621	169,167	248	0	2	0	0	0	2	0
51	Horseshoe Bayou, *St. Mary*..............	1937	400		1,458,924	444,263	476	166	7	1	y	0	5	1
52	Iberia, *Iberia*........	1917	300		24,679,909	2,765,871	3,597	638	92	14	1	0	88	0
53	Iowa, *Calcasieu and Jefferson Davis*.....	1931	1,000		46,238,346	3,394,905	29,250	3,418	97	8	y	2	62	1
54	Jeanerette, *St. Mary*.	1935	300		9,672,296	976,681	1,845	144	28	2		2	18	1
55	Jefferson Island, *Iberia*.............	1938	140		867,231	349,727	894	195	11	3	y	y	9	0
56	Jennings, *Acadia*....	1901	800		76,263,394	4,996,807	15,426	3,838	702	16	1	12	96	3
57	Kenilworth, *St. Bernard*..............	1935	40		108,620	25,741	217	216	2	1		0	1	1
58	Lafitle, *Jefferson*.....	1935	2,600		27,259,242	4,539,122	27,670	5,711	60	9	2	0	57	0
59	Lafourche Crossing, *Lafourche*..........	1939	160		467,614	235,164	1,353	955	6	2	0	0	3	2[2]
60	La Pice, *St. James*...	1939	160		196,648	152,970	4,868	2,342	4	1	0	0	2	2
61	La Place, *St. John the Baptist*............	1938	120		74,799[1]	46,288[1]	3,763	2,612	3	0	0	0	0	3
62	Lake Arthur, *Jefferson Davis*.............	1937	900		935,883	233,786	14,286	4,983	11	1	0	0	10	1
63	Lake Barre, *Terrebonne*..............	1929	500		17,497,939	223,333	703	73	40	0	y	0	22	0
64	Lake Chicot, *St. Martin*................	1941	80		28,106	28,106	39	39	2	2	0	0	2	0
65	Lake Hermitage, *Plaquemines*........	1934	100		152,425	6,360	61	48	4	1	0	1	3	0
66	Lake Long, *Lafourche*	1937	480		1,808,476	552,784	15,589	6,349	16	5	0	0	9	7
67	Lake Mongoulois, *St. Martin*............	1939	30		61,818[1]	52,692[1]	2,337	2,199	3	0	y	0	2	y

TABLE 1.—(*Continued*)

	Oil-Production Methods, End of 1941		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells													
Line Number	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Range of Producing Sands	Number of Sands	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
33	3	0	35			MioU	S	25	8,800–11,300	4	15	D	U. Miocene	12,015
34	10	0	33–52			MioU	S	Por	6,700– 7,600	2	45	DS	U. Miocene	9,498
35	40	21	33			MioU	S	33	2,700– 7,600	8	48	DS	L. Miocene	11,667
						MioL	S	Por	6,150–10,100	5	30	DS		
36	3	0	37			MioU	S	Por	6,400–10,500	4	36	D	U. Miocene	11,098
37	0	17	22			MioU	S	Por	3,074– 3,187		18	DS		9,184
38	85	9	36	0.04	Cockfield	Eoc	S	Por	6,400	1	20	D	Wilcox	11,935
			48		Sparta	Eoc	S	Por	7,600	1	20	D		
			42		Wilcox	Eoc	S	22	8,500	1	100	D		
39	7	0	55			MioU	S	29	8,700–11,600	5	30	D	L. Miocene	12,005
40	2	2	23			Ple	S	20	620– 1,100	2	25	DS	Miocene	12,125
			35			MioU	S	Por	6,700– 8,700	3	25	DS		
41	0	0	44			MioU	S	Por	5,500	1	35	DS	U. Miocene	10,725
42	30	0	35			MioU	S	28	4,100– 6,900	11	33	DS	U. Miocene	7,713
43	21	0	38			MioU	S	32	8,600– 9,450	5	100	DS	U. Miocene	11,440
44	18	24	31			MioU	S	Por	5,220– 5,400	3	30	D	Vicksburg	9,240
			36			MioL	S	Por	6,400– 7,050	9	10	D		
45	159	31	36			MioU	S	33	2,600–10,700	19	20	D	U. Miocene	12,526
46	31	0	36			MioU	S	Por	6,149– 9,980	6	15	D	U. Miocene	12,034
47	22	0	32			MioU	S	Por	8,200– 8,900	5	25	A	Miocene	11,386
48	10	4	30			MioU	S	Por	4,000– 8,750	4	35	DS	Miocene	10,154
			34			MioL	S	Por	9,200–10,100	3	70	DS		
49	0	0				Pli	S	Por	2,500	1	50	DS	U. Miocene	11,500
50	2	0	41	0.12		MioL	S	30	9,750– 7,950	2	35	D	L. Miocene	10,900
51	5	0	38			MioU	S	Por	10,850-11,800	2	27	D	Miocene	12,777
52	69	19	18			Pli	S	Por	800	1	50	DS	U. Miocene	9,968
			24			MioU	S	33	2,800– 8,900	14	85	DS		
53	54	8	30	0.09		MioU	S	Por	3,800– 6,200	5	78	D	Vicksburg	9,287
			40			MioL	S	30	7,050– 8,100	4	70	D		
54	16	2	35			MioU	S	28	6,400–10,250	6	34	D	U. Miocene	11,634
55	9	0	33			MioU	S	30	3,070– 8,740	6	35	DS	U. Miocene	9,921
56	85	11	25			MioU	S	Por	1,000– 1,800	2	16	DS	Vicksburg	10,766
			38			MioL	S	28	5,400– 8,440	6	85	DS		
57	1	0	34.4			MioU	S	Por	10,350–10,600	2	20	D	Miocene	11,469
58	57	0	37			MioU	S	29	4,400–10,000	7	45	D	U. Miocene	12,115
59	3	0	40.5			MioU	S	31	9,350–10,120	4	16	D	U. Miocene	11,000
60	2	0	39.4	0.10		MioU	S	31	7,800	1	50	D	L. Miocene	11,851
			53.2			MioL	S	Por	11,000	1	50	D		
61	3	0	54			MioU	S	32	8,100– 8,900	3	40	D	L. Miocene	11,005
62	10	0	54			MioU	S	30	8,500	1	50	D	L. Miocene	12,088
			55			MioL	S	28	9,900–10,100	2	18	D		
63	5	17	30			MioU	S	Por	3,645		50	DS	Salt	11,333
64	2	0	48			MioU	S	Por	8,150– 9,025		22	D	U. Miocene	9,995
65	0	3	31	0.06		MioU	S	Por	3,190– 9,000	3	23	DS	U. Miocene	9,786
66	9	0	45			MioU	S	Por	9,070–10,416	6	36	DS	U. Miocene	11,347
67	2	0	48.4			MioL	S	33	9,775	1	60	DS	L. Miocene	10,788

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area, Proved Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
68	Lake Pelto, *Terrebonne*	1929	110		2,248,657	366,792	479	54	19	0	*y*	1	13	0
69	Lake Salvador, *St. Charles*	1940	400		657,373	612,534	241	218	3	7	0	0	10	0
70	Lakeside, *Cameron*	1941		300	16,276[1]	16,276[1]	945	945	3	3	0	0	0	3
71	Lake Washington, *Plaquemines*	1931	200		3,065,209	193,315	*y*	*y*	7	0	0	0	7	0
72	Lapeyrouse, *Terrebonne*	1941	40		1,104	1,104	17	17	1	1	0	1	0	0
73	Leeville, *Lafourche*	1931	640		23,129,301	1,612,125	2,342	308	129	6	*y*	16	76	2
74	Lewisburg, *Acadia*	1941	80		1,410	1,410	*y*	*y*	1	1		0	1	0
75	Lirette, *Terrebonne*	1937		850	97,538[1]	63,290[1]	14,003	5,558	7	0	*y*	1	0	6
76	Little Cheniere, *Cameron*	1940	80		10,079	4,963	211	211	1	0	0	1	0	0
77	Lockport, *Calcasieu*	1924	350		14,758,372	304,243	2,663	114	77	0	*y*	3	21	0
78	Neale, *Beauregard*	1940	700		1,169,530	840,463	407	324	16	3	0	3	13	0
79	Nibletts, *Jefferson Davis*	1940	Abandoned		5,390	0	4	0	0	0	0	0	0	0
80	North Crowley, *Acadia*	1937	550		4,828,051	2,010,143	8,403	4,162	44	7		2	41	0
81	North Elton, *Allen*	1939	160		16,716[1]	14,760[1]	972	645	3	0	*y*	0	0	2
82	North Tepetate, *Acadia*	1938	1,600		124,855	26,986	4,276	564	7	0	*y*	0	0	1 6[2]
83	Paradis, *St. Charles*	1939	1,000		1,453,834	1,086,157	1,408	984	21	13	0	0	19	2[2]
84	Pecan Lake, *Cameron*	1941	640		4,399[1]	4,399[1]	148	148	2	2	0	0	1	1[2]
85	Perkins, *Cameron*	1939		40	0	0	146	97	1	0	*y*	0	0	1[2]
86	Pine Prairie, *Evangeline*	1912	100		253,685	253,685	53	53	*y*	10	10	0	10	0
87	Plumb Bob, *St. Martin*	1939	160		283,198	149,047	14	7	4	1		0	4	0
88	Point Au Fer, *Terrebonne*	1941		80	111	111	*y*	*y*	1	1	0	0	0	1[2]
89	Port Allen, *West Baton Rouge*	1941	160		79,891	79,891	179	179	4	4	0	0	4	0
90	Port Barre, *St. Landry*	1929	400		9,849,116	1,037,918	572	109	*y*	11	*y*	4	43	0
91	Potash, *Plaquemines*	1937	160		1,039,349	6,553,667	404	304	15	6	*y*	*y*	13	0
92	Quarantine Bay, *Plaquemines*	1937	1,200		5,051,634	2,298,165	3,431	2,425	38	12	*y*	3	33	0
93	Raceland, *Lafourche*	1938	210		1,774.479	552,591	4,218	2,598	10	2	0	0	8	2
94	Richie, *Acadia*	1941	300		147,559	143,997	*y*	*y*	10	10	0	0	10	0
95	Roanoke, *Jefferson Davis*	1934	920		9,142,252	628,769	1,816	2,642	31	0	*y*	1	15	1
96	St. Gabriel, *Iberville*	1941	800		536,676	536,676			21	21	0	6	21	6
97	St. Martinsville, *St. Martin*	1935	80		1,234,857	105,695	388	47	2	0	0	0	2	0
98	Section 28, *St. Martin*	1940	120		19,198	19,198	187	187	*y*	2	1	*y*	1	1[2]
99	Sorrento, *Ascension*	1928	80		1,145,757	55,488	38	1	11	0	1	0	7	0
100	South Crowley, *Acadia*	1938	200		92,620	75,396	70	59	6	3		1	4	1
101	South Elton, *Jefferson Davis*	1937	80	640	59,190[1]	13,177[1]	1,632	375	1	0	0	0	0	1
102	South Houma, *Terrebonne*	1938	80		475,964	150,103	1,881	0	2	0	*y*	1	1	0
103	South Jennings, *Jefferson*	1936		1,500	131,638[1]	33,683[1]	7,012	1,752	8	2	0	1	0	7
104	Starks, *Calcasieu*	1925	100		3,302,835	142,446	2	0.4	35	0	0	3	21	0

TABLE I.—(*Continued*)

	Oil-Production Methods, End of 1941		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells													
Line Number	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Range of Producing Sands	Number of Sands	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
68	9	4	42.6			Pli	S	Por	1,350	1	25	DS	U. Miocene	7,978
			34			MioU	S	Por	5,200– 6,450	5	47	DS		
69	10	0	34			MioU	S	Por	9,600–10,300	4	34	D	U. Miocene	10,501
70	0	0				MioU	S	Por	9,900	1	70	D	Miocene	11,089
71	7	0	17.8	0.73	Cap rock			Por	1,150			DS	U. Miocene	6,445
72	0	0	37			MioU	S	Por	10,900			D	U. Miocene	10,942
73	16	60	32			MioU	S	Por	3,000– 9,000	29	33	D	U. Miocene	9,732
74	1	0	52			MioL	S	30	10,140		1	D	L. Miocene	10,300
75	0	0	51	0.34		MioU	S	Por	8,450–10,520	2	50	D	U. Miocene	12,165
76	0	0	46.8			MioU	S	28	10,185			D	U. Miocene	10,655
77	7	14	23			Pli	S	Por	1,000– 4,300	3		D	L. Miocene	7,902
			32			MioU	S	Por	5,300– 5,500	2		D		
			41			MioL	S	Por	6,400– 6,600	2		D		
78	13	0	37		Wilcox	Eoc	S	22	8,150–10,800	3	20	D	Wilcox	11,210
79	0	0	42	0.2		MioL	S	Por	11,600	1	16	D	L. Miocene	11,748
80	37	4	38	0.17		MioU	S	Por	7,180	1	26	D	L. Miocene	10,652
			36			MioL	S	Por	7,744– 8,760	5	20	D		
81	0	0	53			MioL	S	Por	7,400	1	15	D	Vicksburg	9,010
82			44			MioL	S	30	7,900– 9,600	4	22	D	Marginulina	9,487
83	19	0	37.4			MioU	S	25	9,900–10,000	2	22	D	U. Miocene	11,555
84	1	0	46			MioU	S	Por	10,140–	1	45	D	L. Miocene	10,820
85	0	0				MioL	S	Por	7,038		25	D	Cockfield	9,450
86	10	0	40.5		Cockfield	Eoc	S	27	7,950	1	50	DS	Wilcox	9,554
87	3	1	30.5			MioL	S	24	8,300– 9,100	2	30	DS	L. Miocene	9,771
88	0	0	57			MioU	S	Por	6,750		10	D	U. Miocene	11,732
89	0	0	36			MioL	S	30	9,500– 9,600	2	20	D	L. Miocene	10,044
90	19	24				MioU	S	Por	1,300			DS	L. Miocene	7,213
			26			MioL	S	32	3,100– 6,100	10	40	DS		
			26			Olig	S	Por	3,600	1	20	DS		
			36		Claiborne	Eoc	S	Por	5,116	1	10	DS		
91	13	0	28	0.10		MioU	S	Por	4,160– 8,680	8	40	DS	U. Miocene	10,027
92	33	0	33			MioU	S	Por	7,719– 8,492		16	D	U. Miocene	10,536
93	8	0	37			MioU	S	Por	7,200–12,100	3	30	D	U. Miocene	12,196
94	10	0	25			MioU	S	Por	3,500	1	15		U. Miocene	4,271
95	9	6	37			MioL	S	26	6,260– 8,850	6	56	D	Vicksburg	10,750
96	21	0	33			MioL	S	28	7,770– 8,600	2	110	D	L. Miocene	10,542
97	2	0	31			MioU	S	Por	5,500–	1	50	D	Heaving shale	9,645
98	1	0	27.3			MioL	S	Por	8,906–10,200	2	25	DS	L. Miocene	11,303
99	4	3	23	0.5		Pli	S	Por	900– 1,300	3	40	DS	L. Miocene	8,004
			33			MioL	S	Por	4,300	1	20	DS		
100	4	0	34	0.10		MioU	S	25	4,634– 7,602	5	15	D	Marginulina	10,272
						MioL	S	Por	8,900	1	17	D		
101	0	0	50			MioL	S	30	8,950	1	30	D	Claiborne	13,210
102	1	0	37.4	0.10		MioU	S	Por	10,300	1	30	D	U. Miocene	11,344
103	0	0	31.9			MioU	S	31	8,600	1	45	D	Marginulina	10,953
104	1	20	31.4			MioL	S	31	8,800– 9,500	2	15	D	Jackson	7,420
			18			Pli	S	Por	570		20	DS	U. Miocene	11,344
			18			MioU	S	Por	740– 3,820	3	15	DS		
			20			MioL	S	Por	4,250– 4,720		15	DS		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area, Proved Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
105	Stella, *Plaquemines*...	1940	500		203,246	182,382	323	304	6	4	0	1	5	0
106	Sulphur Mines, *Calcasieu*..............	1926	200		15,943,607	915,070	1,125	310	130	6	*y*	0	69	0
107	Sweet Lake, *Cameron*	1926	200		5,520,077	758,092	943	111	22	3	*y*	1	16	1
108	Tepetate, *Acadia*	1935	1,000		10,436,479	1,420,869	*y*	*y*	63	0	1	2	33	*y*
109	Timbalier Bay, *Lafourche*.............	1938	80		209,574	53,940	15	4	2	0	0	0	2	0
110	University, *East Baton Rouge*........	1938	900		8,706,386	3,589,060	10,277	6,328	95	7	1	6	77	9
111	Unknown Pass, *Orleans*............	1941	80		3,299[1]	3,299[1]	1	1	2	2	0	1	1	0
112	Vacherie, *St. James*..	1938	40		84,920	27,537	619	201	2	0	*y*	0	1	*y*
113	Valentine, *Lafourche*..	1936	240		5,172,376	512,327	1,917	444	35	2	*y*	6	21	1
114	Venice, *Plaquemines*..	1937	300		3,201,789	1,166,980	2,654	1,010	23	7	0	4	19	0
115	Vermilion Bay, *Iberia*	1939	80		256,795	125,222	286	146	2	0	0	0	2	0
116	Ville Platte, *Evangeline*...............	1937	4,800		14,790,507	6,137,121	74,072	37,833	203	68	1	*y*	182	16
117	Vinton, *Calcasieu*....	1910	300		43,153,153	324,641	2	1	448	7	*y*	5	60	0
118	Welch, *Jefferson Davis*	1902	150		676,233	33,134	84	84	*y*	6	*y*	4	20	1
119	West Bay, *Plaquemines*..............	1940	600		424,798	421,166	359	159	14	13	0	0	14	0
120	West Cote Blanche Bay, *St. Mary*......	1940	180		445,177	342,126	126	96	8	4	0	1	7	0
121	West Gueydan, *Vermilion*.............	1938	160		529,023	145,240	124	6	6	0	0	1	5	0
122	West Hackberry, *Cameron*...........	1927	600		7,941,123	2,162,957	4,162	1,161	83	11	*y*	4	64	2
123	West Lake Verret, *St. Martin*...........	1938	800		955,426	646,283	2,142	1,466	23	16	*y*	0	20	2
124	West Mermentau, *Jefferson Davis*.....	1940			13,984[1]	9,659[1]	550	310	1	0	0	0	0	1
125	Westwego, *Jefferson*..	1941	120		34,490	34,490	261	261	4	4	0	0	4	0
126	White Castle, *Iberville*	1929	200		5,182,332	929,876	2,259	430	25	2	*y*	0	16	0
127	Woodlawn, *Jefferson Davis*.....	1938	400	700	2,746,546	1,171,899	14,472	8,597	32	8	0	0	20	5 2[2]

Line Number	Field, *County*	Year of Discovery	Area, Proved Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]

B. NORTH LOUISIANA

Line Number	Field, *County*	Year of Discovery	Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
128	Ajax, *DeSoto and Natchitoches*........	1941	120		3,620	3,620	0	0	2	2	0	1	1	0
129	Athens, *Claiborne*....	1940		320	2,054[1]	2,054[1]	191	140	1	0	0	1		0
130	Bear Creek, *Bienville*	1937		4,000	44,329[1]	16,299	2,913	1,321	5	0	0		0	5
131	Bellevue, *Bossier*.....	1921	1,360	160	10,393,266	213,981	2,566	66	445	22	9	0	162	0
132	Benson, *DeSoto*......	1928	320		6,494	0	107	0	5	0	0	0	0	0
133	Bethany, *Caddo*.....	1916	20	2,560	[4]	1,555	[4]	[4]	14	0	0	0	2	0
134	Blue Lake, *Sabine*....	1928	340		[5]	12,896	0	0	11	1	3	0	1	0

[4] Included under Waskom.
[5] Previously included under Zwolle.

TABLE I.—(*Continued*)

Line Number	Oil-Production Methods, End of 1941		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells													
	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Range of Producing Sands	Number of Sands	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
105	5	0	40	0.12		MioU	S	32	7,000–10,000	4	15	D	U. Miocene	10,807
106	7	62	27			MioU	S	Por	2,760	—	20	DS	L. Miocene	7,563
			34			MioL	S	Por	4,850– 6,800	4	28	DS		
107	16	0	30			MioU	S	Por	5,600– 7,300	8	30	D	U. Miocene	8,928
108	33[3]	0	41.7			MioL	S	25	8,300– 9,165	2	60	D	L. Miocene	9,447
109	1	1	27.2			MioU	S	Por	5,330– 6,760	2	15	DS	Salt	8,727
110	77	0	36			MioU	S	35	4,200– 7,200	5	10	D	L. Miocene	10,362
			43			MioL	S	Por	9,500	1	30	D		
111	1	0	52			MioL	S	Por	9,890	1	—	D	L. Miocene	10,405
112	1	0	36	0.10		MioU	S	Por	6,345	1	50	DS	L. Miocene	10,012
113	11	10	33			MioU	S	Por	3,800– 6,900	7	50	DS	L. Miocene	10,012
114	19	0	41			MioU	S	30	3,600–10,400	8	65	DS	U. Miocene	10,765
115	2	0	33			MioU	S	Por	10,217–10,760	2	30	DS	U. Miocene	11,603
116	170[3]	12	40–60		Sparta	Eoc	S	21	8,700– 8,900	2	30	D	Wilcox	12,527
			36–46		Wilcox	Eoc	S	21	9,600–10,000	4	35	D		
117	4	56	20			MioU	S	Por	1,850– 3,940	7	15	DS	Salt	6,939
118	2	18	21.6			Pli	S	Por	1,200	1	15	DS	Hackberry	10,358
			47.0			MioL	S	Por	6,120– 7,400	3	5–80	DS		
119	14	0	34			MioU	S	Por	6,260– 7,270	3	20	DS	U. Miocene	7,416
120	7	0	33	0.10		MioU	S	Por	2,000– 9,200	7	30	DS	L. Miocene	9,707
121	3	2	39–62			MioU	S	Por	6,600– 7,150	3	10	D	U. Miocene	9,865
122	57	7	21			MioU	S	25	3,050		39	DS	L. Miocene	10,010
			31			MioL	S	30	4,150– 9,250	6	50	DS		
123	14	6	24–37	0.10		MioU	S	28	1,300– 8,750	10	47	D	L. Miocene	11,678
			35			MioL	S	28	8,850–11,500	2	45	D		
124	0	0	56.6			MioL	S	Por	9,100		10	D	Heterostegina	10,005
125	4	0	36.5			MioU	S	30	9,000	1	30	D	U. Miocene	9,755
126	9	7	28			MioU	S	32	5,150– 8,750	5	196	DS	L. Miocene	9,400
127	17	3	38			MioL	S	30	7,480– 9,200	8	25	D	L. Miocene	10,194

Line Number	Oil-Production Methods, End of 1941		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells								Depth, Avg. Ft.					
	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
B. NORTH LOUISIANA														
128	0	1	42.4		Paluxy	CreL	S	Por	3,209	3,214	5	D	Paluxy	3,500
129	0	0	60.8		Hosston	CreL	S	Por	6,166	6,176	10	DF	Hosston	6,706
130	0	0	58.8		Pettit	CreL	OL	16	6,605	6,780	25	D	Hosston	8,016
					Hosston	CreL	S	12.5	7,215	7,879	15	D		
131	0	162	18–19		Nacatoch	CreU	S	Por	300	425	30	DF	Cotton Valley	6,137
					Rodessa	CreL	OL	Por	1,700	1,900	x	DU		
132	0	0			Paluxy	CreL	S	Por	3,000	3,100	10	A	Paluxy	3,440
133	0	2			Nacatoch	CreU	S	Por	930	1,150	25	A	Mooringsport	3,758
					Washita	CreL	S	Por	2,400	2,490	10	A		
					Paluxy	CreL	S	Por	2,830	3,000	10	A		
134	0	1	41.9–44.9		Chalk Series	CreU	C	Fis	2,100	2,500	x	T	Paluxy	4,503

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
135	Caddo (includes Hosston, Pine Island and Vivian areas), *Caddo*	1905	60,000	5,000	152,762,538	3,027,954	142,946	2,577	4,776	164	135	*y*	1,477	22
136														
137	Carterville-Sarepta, *Bossier, Webster*	1922	4,250		2,757,085	67,858	17,107	10	201	2	2	*y*	28	0
138	Caspiana, *Caddo*	1925		400	0	0	193	44	5	0	1	0	0	0
139	Cedar Grove, *Caddo*	1915		3,840	0	0	[d]	0	18	0	0	0	0	0
140	Clarks, *Caldwell*	1941		160+	0	0	0	0	1	1	0	1	0	0
141	Converse, *Sabine*	1932	5,760		2,290,205	174,721	55	0	199	7	15	*y*	74	0
142	Cotton Valley, *Webster*	1922 1926 1936 1936	14,000		33,358,065	5,468,236	182,198	27,260	453	6	18	53*y*	81*y*	35
143	Cypress Bayou, *LaSalle*	1941	80+		43,409	43,409	11	11	2	2	0	0	2	0
144	Dixie, *Caddo*	1929	1,500		[e]	22,977	[e]	[e]	55	1	8	0	5	0
145	Driscoll, *Bienville*	1936		1,500	12,081[1]	8,075[1]	11,321	2,534	4	0	0	0	0	4
146	Elm Grove, *Bossier and Caddo*	1916	320	14,600	3,426,703	110,091	194,424	446	249	0	17	*y*	39	4
147	Epps, *East and West Carroll*	1928		1,280	0	0	7,548	1,143	5	0	0	1	0	4
148	Funny Louis Bayou, *LaSalle*	1941		160+	0	0	0	0	1	1	0	1	0	0
149	Grand Cane, *DeSoto*	1941	40+		0	0	0	0	1	1	0	1	0	0
150	Greenwood, *Caddo*	1940		320	0	0	0	0	2	1	0	2	0	0
151	Grogan, *DeSoto*	1937	40		28,671	0	0	0	1	0	0	0	0	0
152	Haynesville, *Claiborne and Webster*	1921		6,100	70,406,332	931,526	5,168	788	768	2	33	*y*	291	0
153	Hemphill, *LaSalle*	1941	700		44,200	44,200	0	0	9	9	0	0	9	0
154	Holly, *DeSoto*	1930	80	160	998,586	35,627	160	12						
155	Homer, *Claiborne*	1919	3,020		70,899,981	1,034,057	7,177	436	640	7	0	*y*	320	0
156	Indian Bayou, *LaSalle*	1941	40+						1	1	0	0	1	0
157	Lake Bistineau, *Bienville*	1916		5,200	13,592[1]	12,205[1]	22,217	12,287	28	4	0	0	0	17
158	Larto Lake, *Catahoula*	1941	40+		10,779	10,779	0	0	1	1	0	0	1	0
159	Lisbon, *Claiborne*	1936	8,000	1,000	9,239,281	936,487	10,590	3,036	269	1	21	*y*	175	2
160	Little Creek, *LaSalle*	1941	2,440		426,143	426,143	254	254	48		0	2	43	3
161	Logansport, *DeSoto*	1938		11,000	26,762[1]	26,762[1]	6,353	6,318	11	9	0	0	0	11
162	Longwood, *Caddo*	1926		4,560		3,736[1]	7,748	315	38	0	1	*y*	0	2

Previously included under Caddo.

TABLE 1.—(*Continued*)

Line Number	Oil-Production Methods, End of 1941: Number of Wells		Character of Oil		Producing Formation				Depth, Avg. Ft.				Deepest Zone Tested to End of 1941	
	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness Avg. Ft.	Structure[h]	Name	Depth of Hole Ft.
			19–20.5		Nacatoch	CreU	S	Por	800	1,000	30	Af	Igneous below Eagle Mills Salt	11,419
			28–39		Saratoga-Annona	CreU	C	Fis	1,400	1,700	*x*	Af		
			23–44		Tokio	CreU	S	Por	2,000	2,100	20	Af		
135	0	1,477	26–43		Paluxy	CreL	S	Por	2,300	2,600[7]	*x*	Af		
					Ferry Lake	CreL	A	Fis	2,700		*x*	Af		
					Rodessa	CreL	OL	Por	2,800	2,950[7]	*x*	Af		
136			42–43.8		Sligo	CreL	OL	Por	3,620	3,700	*x*	Af		
					Hosston	CreL	S	Por	3,900	4,000	15	Af		
137	0	28	26–43		Tokio	CreU	S	Por	2,675	3,175[7]	30	A	Cotton Valley	10,070
138	0	0			Nacatoch	CreU	S	Por	800	850	20	N	Cotton Valley	9,141
					Eagleford	CreU	S	Por	2,450	2,475	8	N		
139	0	0			Tokio	CreU	S	Por	2,450	2,500	25	A	Hosston	6,001
140	0	0			Wilcox	Eoc	S	Por	2,173	2,185	12	AM	Wilcox	4,006
141	0	74	38 –45		Saratoga-Annona	CreU	C	Fis	1,600	2,100	*x*	Af	Hosston	8,929
			41.5–42		Paluxy	CreL	S	Por	3,406	3,426	20	Af		
			27 –29.5		Ozan	CreU	S	27	2,500	2,600	30	A	Cotton Valley	9,198
142	*y*	*y*	51 –53		Rodessa	CreL	S & L	24	3,900	4,700[7]	35	A		
			49.2–66.9		Hosston	CreL	S	17	5,500	5,800[7]	10	A		
			41 –65		Cotton Valley	Jor	S	17	7,900	8,650[7]	40	A		
143	2	0	44		Wilcox	Eoc	S	22	4,750	4,765	15	AM	Midway	5,976
144	0	5	38.4		Paluxy	CreL	S	Por	2,400	2,475	10	T	Mooringsport	3,514
145	0	0			Rodessa	CreL	OL	16	5,860	5,885	15	D	Hosston	7,693
					Hosston	CreL	S	12	7,160	7,220	25	D		
146	0	39			Nacatosh	CreU	S	Por	800	1,000	30	A	Cotton Valley	8,647
			29–30.4		Ozan	CreU	S	Por	1,550	1,750	12	A		
					Tokio	CreU	S	Por	1,675	1,930[7]	50	A		
					Paluxy	CreL	S	Por	2,400	2,500	10	A		
147	0	0			Monroe gas rock	CreU	C	Por	2,302	2,356	25	D	Eagleford	2,820
148	0	0			Sparta	Eoc	S	Por	1,465	1,475	10		Wilcox	4,000
149	0	0	42.6		Paluxy	CreU	C	Por	2,820	2,858	10		Austin	2,858
150	0	0			Paluxy	CreL	S	Por	2,549	2,606	20	AM	Paluxy	2,981
151	0	0	38–39		Paluxy	CreL	S	Por	2,929	2,934	5	D	Paluxy	2,961
			34.5–36		Tokio	CreU	S	Por	2,725	2,875	25	A	Smackover	11,254
152	2	289	34.8		Rodessa	CreL	OL	Por	4,250	4,400	20	AL		
			38 –41.5		Sligo	CreL	OL	18	5,200	5,440	20	AL		
153	8	1	38.5–41.4		Wilcox	Eoc	S	28	3,623	3,988[7]	60	AM	Midway	5,301
154			37–39.2		Eagleford	CreU	S	Por	2,538	2,581	11	NL	Paluxy	3,373
155	0	320	35.4–37.8		Nacatoch	CreU	S	Por	1,000	1,400	50	DF	Cotton Valley	4,504
			35 –38		Tokio	CreU	S	Por	1,900	2,000	50	DF		
156	1	0	43.6		Wilcox	Eoc	S	Por	4,294	4,304	10		Midway	5,905
157	0	0			Ozan	CreU	S	Por	1,950	2,100	25	AF	Cotton Valley	8,532
					Tokio	CreU	S	Por	2,525	2,675	25	AF		
					Sligo	CreL	OL	16.5	5,000	5,350	40	AF		
					Cotton Valley	Jur	S	12	8,400	8,532	*y*	AF		
158	1	0	46.4		Wilcox	Eoc	S	22	5,108	5,133	25		Midway	7,031
159	*y*	*y*	32.1–33		Sligo	CreL	OL	18.4	5,100	5,350	10	DL	Eagle Mills	11,834
			42		Hosston	CreL	S	Por	5,300	5,400	7	DL		
					Cotton Valley	Jur	S	13	8,400	8,800[7]	30	DL		
			55.6		Smackover	Jur	L	Por	10,150	10,400	100	D		
160	6	37	30–38.2		Wilcox	Eoc	S	28	2,353	3,590[7]	180	A	Midway	4,124
161	0	0			Rodessa	CreL	OL	18	4,825	5,020	50	A	Hosston	6,271
					Sligo	CreL	OL	12	5,980	6,000	20	A		
162	0	0			Nacatoch	CreU	S	Por	870	970	40	A	Hosston	6,065
					Paluxy	CreL	S	Por	2,690	2,775	20	A		
					Sligo	CreL	OL	Por	5,590	5,630	40	A		
					Hosston	CreL	S	Por	6,000	6,050	50	A		

[7] Range of producing sands.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
163	Monroe, *Morehouse, Ouachita, Union*	1916		251,000	0	0	3,031,953	216,689	1,416	48	6	*y*	0	1,295
164	Nebo, *LaSalle*	1940	2,800		889,215	889,215	1,298	1,298	68	61	0	0	66	2
165	NE. Lisbon, *Claiborne*	1941		320+			0	0	1	1	0	1	0	0
166	Oakland, *Union*	1928	40		*x*	2,106	0	0		0	0	0	1	0
167	Olla, *LaSalle*	1940	8,300		5,224,773	4,249,582	3,429	3,382	190	97	0	2	184	4
168	Pleasant Hill, *DeSoto and Sabine*	1927	2,000		1,468,294	30,007	348	73	64	2	5	*y*	25	1
169	Red River—Bull Bayou, *Red River, DeSoto*	1912	37,000	3,000	56,762,319	371,988	67,789	1,416	1,440	1	16	*y*	120	24
170	Richland, *Richland*	1926		49,280			460,619	0	313	0	0	0	0	0
171	Rodessa, *Caddo*	1930	10,000	8,000	71,691,280	5,239,291	418,320	70,523	504	0	9	24[8]	323	125
172	Ruston, *Lincoln*	1937		320	0	0	0	0	1	0	0	0	0	1
173	Shongaloo, *Webster*	1921	150	5,600	168,096	16,237	98,123	187	94	0	0	*y*	0	2
174	Shreveport, *Caddo*	1913	2,200	6,000	4,576,145	1,002,226	7,242	1,220	56	0	1	3	45	0
175	Sibley, *Webster*	1936		1,000	14,360[1]	7,833[1]	3,576	2,232	6	2	0	0	0	6
176	Simsboro, *Lincoln*	1935		700	4,680[1]	3,244[1]	7,622	1,309	2	0	0	1	0	1
177	Sligo, *Bossier*	1922	2,000	13,000	2,552,362	837,555	135,367	25,359	159	22	7	*y*	47	41
178	South Jena, *LaSalle*	1941	600		40,604	40,604	0	0	7	7	0	0	7	0
179	Spider, *DeSoto*	1914		500	0	0	341	0	5	0	0	0	0	0
180	Spring Ridge, *Sabine*	1931	40	160	*x*	0	0	0	2	0	0	0	0	0
181	Standard, *LaSalle*	1940		1,000	0	0	186	186	3	1	0	2	0	1
182	Sugar Creek, *Claiborne*	1930	440	4,000	1,084,389	493,638	59,975	8,468	31	9	0	3	9	16
183	Summerville, *LaSalle*	1940	700		45,903	45,903	415	415	9	8	1	0	7	1
184	Sutherlin, *DeSoto*	1920		1,280	0	0	224	0	4	0	0	0	0	0
185	Trout Creek, *LaSalle*	1941	700		8,356	8,356	0	0	5	5	0	2	3	0
186	Tullos—Urania—Georgetown, *Grant, LaSalle, Winn*	1925	6,600		25,108,334	790,095	0	0	529	7	*y*	*y*	241	0
187	Waskom, *Caddo*	1924		1,600	25,998	3,213[1]	12,418	410	32	0	3	*y*	0	3
188	White Sulphur Springs, *LaSalle*	1927	350		12,290	0	0	0	12	0	0	0	0	0
189	Willow Lake, *Catahoula*	1941	80+		5,268	5,268	0	0	2	2	0	0	2	0
190	Zenoria, *LaSalle*	1938	160		[9]	3,747	0	0	7	3	1	*y*	2	0
191	Zwolle, *Sabine*	1928	28,000		14,428,112	387,963	180	0	382	1	5	*y*	50	0

[8] Includes three input wells.
[9] Included in Tullos-Urania total.

TABLE 1.—(*Continued*)

	Oil-Production Methods, End of 1941		Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells								Depth, Avg. Ft.					
Line Number	Flowing	Artificial Lift	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
163	0	0			Monroe gas rock	CreU	C	Por	2,145	2,205	30	MC	Morehouse	10,475
						CreU	S	Por	2,265	2,430	10	MC		
164	38	28	39–43.2		Wilcox	Eoc	S	25	3,359	4,090[7]	315	AL	Midway	5,093
165	0	0	65.1		Hosston	CreL	S	Por	5,100	5,180	35	N	Hosston	6,185
166	0	1				CreU	S	Por	2,200	2,300	10		U. Cretaceous	3,001
167	82	102	26.1–31.7		Wilcox	Eoc	S	20	2,040	2,790[7]	154	AL	Lower Glen Rose	8,997
168	0	25	40.4–42.5		Paluxy	CreL	S	Por	3,100	3,250	15	N	Mooringsport	5,063
169	0	120			Nacatoch	CreU	S	Por	725	1,000	30	AF	Hosston	6,479
					Saratoga-Annona	CreU	C	Por	850	1,050	x	AF		
					Paluxy	CreL	S	Por	2,450	3,500[7]	10	AF		
170	0	0			Tokio	CreU	S	Por	2,349	2,447	76	A	Cotton Valley	9,986
171	142	181	40–70		Rodessa	CreL	S, L, OL	15–25	5,400	6,100[7]	125	AF	Eagle Mills	11,486
172	0	0			Sligo	CreL	OL	Por	5,300	5,325	20	A	Hosston	5,822
173	0	0	29		Tokio	CreU	S	20	2,600	2,675	15	A	Cotton Valley	10,462
			49.8–64.8		Cotton Valley	Jur	S	10	8,850	9,200[7]	30	A		
174	16	29			Nacatoch	CreU	S	Por	875	1,025	25	A	Cotton Valley	8,690
					Tokio	CreU	S	Por	2,450	2,500	10	A		
					Sligo	CreL	OL	18	5,550	5,620	15	A		
175	0	0	58.2		Rodessa	CreL	OL	15	5,500	5,750	35	A	Cotton Valley	10,383
176	0	0			Rodessa	CreL	OL	17	5,280	5,292	12	D	Cotton Valley	10,002
					Hosston	CreL	S	12.5	6,460	6,540	25	D		
177	0	47			Nacatoch	CreU	S	Por	830	1,060	40	Df	Hosston	6,112
					Ozan	CreU	S	Por	1,600	1,800	15	Df		
					Tokio	CreU	S	Por	2,460	2,630	10	Df		
					Paluxy	CreL	S	Por	2,640	2,810	15	Df		
			41 –42.5		Mooringsport	CreL	L	Por	3,000	3,200	10	Df		
			56.7		Rodessa	CreL	OL	15	4,150	4,450	30	Df		
			49.5–49.9		Sligo	CreL	OL	17	4,925	5,275	50	Df		
178	7	0	33–43.4		Wilcox	Eoc	S	26	3,272	3,776[7]	51	NL	Midway	5,062
179	0	0			Paluxy	CreL	S	Por	2,800	3,100	20	A	Hosston	6,063
180	0	0	39		Paluxy	CreL	S	Por	3,350	3,370	5	D	Mooringsport	3,723
181	0	0			Wilcox	Eoc	S	28	2,164	2,485[7]	52	NL	U. Cretaceous	5,097
182	9	0			Rodessa	CreL	OL	18	4,300	4,600	13	A	Cotton Valley	10,759
			32.4–37		Sligo	CreL	OL	14	4,900	5,500[7]	50	A		
			34 –34.2		Hosston	CreL	S	25	5,550	5,820	18	AL		
183	0	7	28.4–33		Wilcox	Eoc	S	20	2,512	3,167[7]	45	NL	Midway	4,071
184	0	0			Paluxy	CreL	S	Por	2,775	2,925	10	D	Paluxy	3,003
185	3	0	35.2–43.2		Wilcox	Eoc	S	28	3,168	3,614[7]	49	NL	Midway	4,810
186	0	241	21.1–22.1		Wilcox	Eoc	S	Por	1,490	1,609	9	Nf	Tokio	6,463
187	0	0			Nacatoch	CreU	S	Por	925	1,075	30	A	Hosston	6,400
					Tokio	CreU	S	Por	1,875	2,350[7]	50	A		
					Paluxy	CreL	S	Por	2,540	2,750	30	A		
					Hosston	CreL	S	12.5	6,157	6,185	15	A		
188	0	0	20		Cockfield	Eoc	S	Por	794	804	9	NF	Wilcox	2,435
189	2	0	36.5		Wilcox	Eoc	S	22	5,533	5,539	20		Midway	6,810
190	0	2	19–20		Wilcox	Eoc	S	Por	1,612	1,684	9	T	Midway	4,072
191	0	50	41.5		Annona	CreU	C	Fis	2,100	2,500	x	A	Rodessa	6,178

TABLE 2.—*Wildcat Wells Completed in Louisiana during* 1941

Parish	Operator	Lease and Well Number	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Twp.	Rge.				
SOUTH LOUISIANA									
Acadia	Danciger O. & R. Co.	Mrs. L. D. Thibodaux No. 1	73	7 S	2 E	9/24/41	9,514	L.Miocene	Church Point Prospect
Allen	W. T. Burton	Calcasieu Nat. Bank No. 1	21	5 S	3 W	8/27/41	10,980	Claiborne	S. E. Oberlin area
	F. K. Campbell	James Bowles No. 1	14	3 S	6 W	9/19/41	7,795	Oligocene	
	J. A. Hafner	Pierce Nevils No. 1	10	7 S	6 W	12/10/41	8,014	Oligocene	Indian Village area
Assumption	Geo. Echols	Armelise Planting Co. No. 1	14	12 S	12 E	10/25/41	8,897	Miocene	Napoleonville dome. Salt 8897 ft.; various cores showing oil—too tight
	Shell	State Grassy Lake No. 1		15 S	13 E	1/11/41	10,804	Miocene	
Beauregard	Atlantic Ref. Co.	Rice Ld. & Lbr. Co. No. D-1	30	4 S	10 W	6/19/41	10,002	Wilcox	Test in Newlin area, 6 mi. SE. Neale field
	Humble O. & R. Co.	Edgewood Land & Logging Co. No. B-1	25	6 S	10 W	7/18/41	11,541	Wilcox	Test on Abbie Joe prospect; had show but unable to test because of mechanical difficulties
Calcasieu	Hecate, Inc.	A. S. Vincent No. 1	36	10 S	10 W	9/—/41	3,140	U.Miocene	No date of abandonment
	Gulf Ref. Co.	Calcasieu Nat. Bank No. 1	18	11 S	5 W	7/21/41	10,534	L.Miocene	Blew out and caught fire
	Pan-American	La. Farm & Livestock No. 1	8	11 S	9 W	8/ 7/41	10,411	L.Miocene	Moss Lake prospect
Cameron	John Mayo	Cameron Par. Sch. Bd. No. 1	16	15 S	14 W	7/ 7/41	6,010	Miocene	
E. Baton Rouge	Texas Progress Oil Co.	Nelson No. 1	74	8 S	1 E	12/ 7/41	10,310	L.Miocene	
Evangeline	Bering Oil Co.	U. G. Z.-Fruge No. 1	10	6 S	2 W	2/23/41	8,075	Oligocene	North Basile prospect
	The Texas Co.	LaDanois Land & Stone Co. No. 1	35	3 S	1 W	11/18/41	9,993	Sparta	Test on SW. flank Pine Prairie; 2 mi. W. of production and 500 ft. low.
Iberia	Gulf Ref. Co.	Petit Anse No. 1	59	13 S	6 E	6/ 4/41	12,012	Miocene	Sidetracked to 9545 ft.
	Plymouth Oil Co.	F. B. Williams Cypress Co. No. 1	33	12 S	11 E	9/13/41	11,850	Miocene	3 mi. SE. Bayou Pigeon field
Iberville	Congo Oil Co.	Dreyfuss No. 1	61	7 S	9 E	8/15/41	10,008	L.Miocene	Rosedale prospect
Jefferson	Titanic Oil Co.	Marrero Land Co. No. 1	2	13 S	22 E	1/18/41	10,004	U.Miocene	Temporarily completed Westwego field, then junked
Lafourche	Gulf Ref. Co.	State Lease No. 7, No. 192-"PP"	8	21 S	21 E	10/ 1/41	12,905	U.Miocene	
	Gulf Ref. Co.	State "PP" No. 1		23 S	23 E	9/19/41	3,004	U.Miocene	Bay Marchand, rig destroyed by storm
Plaquemine	Phillips Petr. Co.	State No. 1	48	20 S	29 E	3/24/41	12,280	U.Miocene	
St. Bernard	The California Co.	Biloxi Marsh Lds. Co. No. 1	25	12 S	16 E	3/12/41	11,173	U.Miocene	Blew out at 8775 ft., 1940; possible gas show 8506–8508 ft.
St. Helena	Humble O. & R. Co.	Great Southern Lbr. Co. No. 1	20	1 S	5 E	9/19/41	8,333	Wilcox	
St. Landry	Bowles, W. V.	Hidalgo "PP" No. 1	26	6 S	3 E	7/30/41	8,536	L.Miocene	
	Brewster & Bartle	C. Richard No. 1	25	8 S	3 E	8/30/41	9,010	L.Miocene	
	Sun Oil Co.	Boagni Core Tract No. A-1	48	8 S	4 E	7/ 3/41	1,538	Pliocene	Core test well
	Sun Oil Co.	Boagni Core Tract No. A-2	49	8 S	4 E	7/15/41	1,541	Pliocene	Core test well
	Sun Oil Co.	Savoie Core Tract No. A-1	13	8 S	3 E	7/23/41	1,473	Pliocene	Core test well
St. Martin	Bennett, F. W.	Darby Est. No. 1	56	11 S	6 E	1/10/41	9,526	U.Miocene	
	Helis, Wm.	J. J. Marin No. 1	32	9 S	7 E	1/27/41	1,181		Section 28 dome
	Shell	Grassy Lake No. 1	11	15 S	13 E	1/13/41	10,804	U.Miocene	
St. Mary	Baldwin Minerals	Adeline Sugar Co. No. 1	55	14 S	9 E	5/ 1/41	2,646	U.Miocene	
	Bateman, E. G., et al.	W. P. Foster No. 1	38	15 S	9 E	3/31/41	10,952	U.Miocene	Several oil and gas shows reported
	Helis, Wm.	Avoca, Inc. No. 1	45	16 S	13 E	5/27/41	11,027	U.Miocene	Avoca Island prospect
	Humble O. & R. Co.	Miami Corp. No. C-1	15	15 S	6 E	3/ 7/41	11,215	U.Miocene	Cypremort Point
	The Texas Co.	State Cote Blanche Is. No. 2		15 S	7 E	4/11/41	5,454	U.Miocene	1882 sandy limestone with salt

TABLE 2.—(*Continued*)

Parish	Operator	Lease and Well Number	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Twp.	Rge.				
	The Texas Co.	State Rabbit Is. No. 1				1/16/41	8,245	U.Miocene	Oil show at 5850 ft.; in Atchafalaya Bay
St. Tammany..	Burton W. T.	State Lake Pontchartrain No. 5		8 S	10 E	2/22/41	8,300	Miocene	
	Burton, W. T.	State Lake Pontchartrain No. 6				4/ 6/41	9,335	Miocene	In lake
Terrebonne....	Barnsdall	Nelson Development Co. No. 2	3	21 S	11 E	1/13/41	11,401	U.Miocene	Pointe Au Fer
	Bering Oil Co.	Mrs. Willie A. Land No. 1	9	16 S	16 E	5/17/41	10,522	U.Miocene	
	Sinclair-Prairie	Aragon Plant. No. 1	5	18 S	19 E	4/27/41	11,620	U.Miocene	Bourg area
	Sinclair-Prairie	H. U. Duplantis No. 1	12	18 S	18 E	7/27/41	11,007	U.Miocene	Bourg area
	Stanolind Oil & Gas Co.	Continental Ld. & Fur Co. No. 1	34	17 S	14 E	2/24/41	11,010	U.Miocene	Piquant area
	Stanolind Oil & Gas Co.	Realty Operators, Inc. No. 1	102	17 S	17 E	6/10/41	11,328	U.Miocene	
	The Texas Co.	State Coon Point No. 5				3/30/41	10,080	U.Miocene	Caillou Island Bay
Vermilion......	Cities Service Co.	Homeseekers Dev. Co. No. 1	11	11 S	1 E	6/22/41	10,505	U.Miocene	
					NORTH LOUISIANA				
Avoyelles......	Cockburn, Hargrove & Bateman (W. C. Brock)	Snowden Est. No. 1	22	3 N	5 E	9/18/41	7,210	Wilcox	Lake Latagnier prospect; show 6693–6695 ft. in Wilcox; tested oil and salt water
	J. A. Humphrey	P. Frazee No. 1	6	3 N	3 E	8/19/41	6,390	Wilcox	
	S. W. Richardson	Haas Land Co. No. 1	30	1 S	2 E	6/16/41	8,848	Wilcox	Wilcox test between Cheneyville and Eola
Bossier........	R. L. Reese	Bellevue Ld. Co. No. 1	27	20 N	11 W	6/23/41	3,135	L.Cre.	NW. flank Bellevue structure; perf. 2847–2857 ft. tested salt water
	G. D. Stevens	Bellevue Ld. Co. No. 1	27	20 N	11 W	5/30/41	3,005	L. Cre.	NW. flank Bellevue structure; show 2831–2849 ft. tested salt water
Caldwell.......	Carter Oil Co.	La. Central Lbr. Co. No. 1	22	13 N	2 E	12/19/41	3,257	L.Wilcox	
	D. J. Crawford	La. Central Lbr. Co. No. 1	30	12 N	4 E	1/24/41	2,524	Wilcox	
	D. Frankel, Jr.	La. Central Lbr. Co. No. 1	7	11 N	4 E	9/26/41	3,501	Wilcox	
	Mudge Oil Co.	International Paper Co.	5	11 N	4 E	12/10/41	3,516	Wilcox	
	V. V. Ryan	La. Central Lbr. Co. No. 1	16	12 N	4 E	1/25/41	3,020	Wilcox	
Catahoula.....	O. C. Borah	G. C. Womack No. 1	54	9 N	5 E	11/ 7/41	5,572	U.Midway	
	Carter Oil Co.	Tensas Delta No. 1-G	30	6 N	5 E	12/19/41	6,197	U.Midway	
	Delta Drill. Co. & H. H. Coffield	W. R. Davis, Inc. No. 1	1	4 N	5 E	12/15/41	5,325	Wilcox	Stuck drill pipe and moved to new loc. for W. R. Davis No. A-1
	Delta Drill. Co. & H. H. Coffield	W. R. Davis, Inc. No. A-1	1	4 N	5 E	12/28/41	6,252	Wilcox	
	Roy L. Fisher	J. W. Bradford No. 1	29	7 N	5 E	9/16/41	5,885	U.Midway	
	H. L. Hunt	B. D. Anderson No. 1	31	10 N	6 E	3/ 2/41	5,215	L.Wilcox	
	H. L. Hunt	Goodpine Oil Co. No. F-21	9	10 N	5 E	9/24/41	5,040	L.Wilcox	
	H. L. Hunt	La. Central Lbr. Co. No. A-2	9	9 N	6 E	11/ 2/41	9,451	L.Cre.	Deep test well drilled near Harrisonburg
	H. L. Hunt	La. Hdw. Tensas Delta No. A-1	7	4 N	5 E	12/ 6/41	6,680	Wilcox	
	H. L. Hunt	Southern Craft Lbr. Co. No. 1	19	10 N	6 E	3/24/41	5,250	L.Wilcox	
	C. H. Lyons	Q. A. Harais No. 1	18	7 N	6 E	12/13/41	6,349	U.Midway	
	Phillips Petr. Co.	Tensas Delta No. F-1	21	6 N	5 E	12/25/41	6,350	U.Midway	

TABLE 2.—(*Continued*)

Parish	Operator	Lease and Well Number	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Twp.	Rge.				
	Placid Oil Co.	Calvert, et al. No. 1	35	7 N	6 E	12/21/41	6,573	L.Wilcox	
	Placid Oil Co.	Grant Tbr. & Mfg. Co. No. 1	21	7 N	6 E	12/13/41	6,591	U.Midway	
	Placid Oil Co.	La. Central Lbr. Co. No. A-3	21	10 N	6 E	12/20/41	4,617	L. Wilcox	
Claiborne......	R. H. Crow	T. F. O'Bannon No. 1	30	22 N	4 W	8/14/41	5,431	Hosston	N. flank Lisbon structure, 4 mi. from production
	Skelly Oil Co.	J. G. Dance No. 1	31	20 N	6 W	6/28/41	6,708	Hosston	Defined Pettit production at Athens ½ mi. E. of production and 215 ft. lower on base Ferry Lake
	H. R. Wright, Jr.	Mrs. A. M. Rainach No. 1	16	22 N	5 W	5/ 7/41	5,513	Hosston	Sligo test on NW. flank Lisbon structure 6 mi. from production
Concordia.....	True Cauble	Gen. Am. Ins. Co. No. 1	44	7 N	6 E	12/23/41	6,220	Wilcox	
	Elliot & Woodley	Elkhorn Plant., et al. No. 1	33	8 N	8 E	12/16/41	6,587	Wilcox	
	J. K. Hughes	D. L. Nelson No. 1	34	9 N	10 E	3/22/41	2,384	Sparta	
	J. K. Hughes & C. M. Barnes	Merrill No. 1	23	7 N	9 E	11/12/41	6,760	Wilcox	
De Soto.......	W. L. Hamilton	S. A. Kidd No. 1	36	12 N	14 W	6/—/41	2,068	U.Cre.	
	The Hunter Co.	Mrs. I. S. Baker No. 1	6	11 N	14 W	12/27/41	6,063	Hosston	Sligo test in old Spider area
	G. H. Neighbors	I. D. Bufkin Est. No. 1	11	10 N	11 W	6/24/41	3,310	Paluxy	1½ mi. NW. production at Ajax
	G. H. Neighbors	C. R. King No. 1	12	10 N	11 W	8/23/41	3,300	Paluxy	½ mi. N. of production at Ajax
	Schubert Oil Co.	Scott No. 1	29	14 N	13 W	4/15/41	3,007	L.Cre.	Old Holly area
Franklin.......	Crown Central Petr. Corp.	H. B. Womble No. 1	11	12 N	8 E	7/28/41	4,510	Wilcox	About 4 mi. S. of Gilbert salt dome
	Grubb & Hawkins	J. H. Campbell No. 1	1	11 N	7 E	8/30/41	4,526	Wilcox	Extension area
	H. L. Hunt	Chicago Mills Lbr. Co. No. 6	21	12 N	9 E	10/ 1/41	4,485	Wilcox	
	J. M. Rush	M. V. Moore No. 1	13	11 N	6 E	4/14/41	4,503	Wilcox	
	J. B. White, et al.	A. M. Dailey	1	11 N	6 E	4/ 1/41	3,016	Wilcox	
Grant.........	Bering Oil Co.	Goodpine Oil Co. No. 1	18	8 N	1 W	1/26/41	4,658	U.Midway	
	R. C. Bowers	Matheson Est. No. 1	15	9 N	1 E	6/ 2/41	1,602	Wilcox	Georgetown area
	Bert Fields	J. T. McManus No. 1	8	8 N	4 W	6/ 5/41	3,560	Wilcox	
	Herton Oil Co.	J. H. McNeely Est. No. 1	10	6 N	3 E	9/14/41	5,509	Wilcox	
	H. L. Hunt	Goodpine No. F-1	12	8 N	2 W	8/18/41	4,805	U.Midway ?	
	H. L. Hunt	Goodpine No. F-4	16	8 N	1 E	10/13/41	4,643	U.Midway	
	H. L. Hunt	Goodpine No. F-5	22	8 N	1 W	10/27/41	5,075	U.Midway	
	H. L. Hunt	Goodpine No. F-6	29	9 N	1 E	9/21/41	4,273	U.Midway	
	H. L. Hunt	Goodpine No. F-7	24	8 N	1 W	9/25/41	4,060	Wilcox	
	H. L. Hunt	Goodpine No. F-10	34	9 N	1 W	10/19/41	4,576	U.Midway	
	E. F. Neely	A. McAdams No. 1	19	6 N	2 E	8/17/41	4,634	Wilcox	
	Placid Oil Co.	Goodpine No. F-122	2	8 N	2 W	12/24/41	4,666	Midway	
	Loyd H. Smith, et al.	Swope No. 1	16	9 N	1 E	6/ 2/41	3,995	U.Midway	Georgetown area
La Salle.......	O. K. Allen, Jr.	La. Central Lbr. Co. No. A-1	29	9 N	3 E	9/25/41	3,511	Wilcox	
	Allen & Breedlove Oil & Gas Co.	M. Powell Est. No. 1	32	11 N	3 E	1/16/41	2,350	Wilcox	Standard area
	Ark. Fuel Oil Co.	Tremont Lbr. Co. No. D-2	13	9 N	1 E	7/ 8/41	3,352	Wilcox	
	R. J. B. Abshire	Urania Lbr. Co. No. 1	10	10 N	2 E	12/ 8/41	2,483	Wilcox	Wildcat drilled between Olla and Urania fields
	Carter Oil Co.	Tensas Delta No. 1-E	5	5 N	4 E	10/26/41	6,095	Wilcox	
	H. L. Hunt	Goodpine Lbr. Co. No. C-5	27	8 N	3 E	9/ 6/41	5,187	U.Midway	
	H. L. Hunt	Goodpine Lbr. Co. No. F-16	11	8 N	2 E	12/10/41	4,510	U. Midway	Wilcox test between Trout Creek and Little Creek oil fields
	H. L. Hunt	Goodpine Lbr. Co. No. F-18	4	6 N	3 E	9/ 8/41	5,201	L. Wilcox	

TABLE 2.—(*Continued*)

Parish	Operator	Lease and Well Number	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Twp.	Rge.				
	H. L. Hunt	Goodpine Lbr. Co. No. F-19	36	9 N	4 E	9/ 7/41	5,460	L.Wilcox	
	H. L. Hunt	Goodpine Lbr. Co. No. F-121	37	7 N	3 E	11/ 5/41	5,197	U.Midway	Wilcox test NE.of Nebo field
	The Hunter Co., Inc.	Pipes No. 1	18	8 N	3 E	1/18/41	4,010	Wilcox	
	E. A. Landreth	Tremont Lbr. Co. No. B-1	14	9 N	2 E	6/29/41	3,111	Wilcox	Test well between Olla and Summerville fields
	Little River Oil Co.	A. A. Whatley et al.	18	7 N	2 E	6/27/41	3,680	Wilcox	Wilcox test on W. flank of White Sulphur Springs structure
	Louark Prod. Co. Phillips Petr. Co.	Tensas Delta No. 1	27	6 N	4 E	3/ 4/41	5,510	U.Midway	
	Joe L. May & Dan Whatley	La. Delta Hdw. Lbr. Co. No. 1	20	7 N	4 E	9/13/41	5,367	U.Midway	
	Phillips Petr. Co.	Tensas Delta No. I-1	1	5 N	4 E	11/13/41	6,472	U.Midway	
	Placid Oil Co.	C. F. Coon No. 1	39	7 N	4 E	12/18/41	5,171	U.Midway	
	Placid Oil Co.	Goodpine Lbr. Co. No. F-15	15	8 N	4 E	12/29/41	5,405	U.Midway	
	Placid Oil Co.	Goodpine Lbr. Co. No. F-17	2	8 N	3 E	12/14/41	5,052	U.Midway	
	Placid Oil Co.	Tremont Lbr. Co. No. A-3	18	9 N	2 E	4/26/41	4,151	U.Midway	Wilcox test on W. flank of Little Creek structure
	Placid Oil Co.	Tremont Lbr. Co. No. A-5	8	9 N	2 E	6/12/41	3,873	L.Wilcox	Wilcox test between Olla Field and Little Creek structure
	Placid Oil Co.	Urania Lbr. Co. No. A-1	17	8 N	2 E	12/29/41	4,472	U.Midway	
	Harry Shulman, et al.	C. B. Walker No. 1	13	7 N	3 E	11/24/41	4,500	Wilcox	SE. of Nebo, NE. of Hemphill
	Harry Shulman	V. B. Whiddon No. 1	9	9 N	3 E	Temporarily abandoned, 1/22/41			
	Sinclair Prairie Oil Co.	Goodpine Oil Co. No. 1	28	9 N	3 E	1/13/41	4,515	U.Midway	
	N. H. Wheless	La. Delta Hdw. Lbr. Co. No. 1-A	26	7 N	4 E	11/ 3/41	5,713	U.Midway	Wilcox test well NW. of Cypress Bayou field
	N. H. Wheless	La. Delta Hdw. Lbr. Co. No. 1-B	3	5 N	3 E	12/12/41	5,996	U.Midway	
Lincoln........	Herman Brown	Ark.-La. Gas Co. No. 1	11	17 N	4 W	5/ 4/41	10,003	Cotton Valley	Old dry hole on E. flank Simsboro deepened from 7023 ft.
	H. L. Hunt	Ayer Tbr. Co. No. 3	18	15 N	10 E	8/ 8/41	3,584	Wilcox	
	H. L. Hunt	W. A. Lancaster No. 1	3	14 N	12 E	2/26/41	6,725	U.Cre.	
Morehouse.....	Union Prod. Co.	C. H. Hinkle No. 1	3	21 N	7 E	6/26/41	3,000	L.Cre.	
	Union Prod. Co.	E. M. White No. 1	37	20 N	6 E	5/ 2/41	2,425	U.Cre.	
Natchitoches...	Carter Oil Co.	Culpepper No. 1	36½	8 N	7 W	8/27/41	3,330	Wilcox ?	
	Clark & Cowden	Pierson No. 1	27	8 N	6 W	6/ 2/41	4,101	U.Midway	
	E. H. Demetrio	J. I. Winn No. 1	25	10 N	10 W	10/ 7/41	1,900	U.Cre. ?	
	H. L. Hunt	Goodpine No. F-14	36	13 N	6 W	11/17/41	5,788	L.Cre.	
	W. H. Jacobson	Leopold Plant. No. 1	33	11 N	9 W	9/ 4/41	1,327	Midway	
	Rhodes & O'Meara	Prud. Life Ins. Co. No. 1	36	11 N	10 W	8/ 9/41	6,001	Sligo	On Lake End prospect
	J. L. Trentman	Brown Lbr. Co. No. 1	31	11 N	10 W	12/ 4/41	3,510	Paluxy	
Rapides.......	Chamblee & Pitts	Lee Lbr. Co., Ltd.	6	5 N	3 E	6/19/41	5,010	Wilcox	Taken over by M. H. Marr at 4570 ft.
	Crosby Drill. Co.	J. B. Phillips No. 1	15	1 S	2 W	3/ 4/41	8,360	Wilcox	Glenmora area
	M. H. Marr	Lee Lbr. Co. No. 1-A	6	5 N	3 E	9/ 3/41	6,120	Wilcox ?	
	Navarro Oil Co.	D. K. Cooper No. 1	54	4 N	2 W	4/28/41	7,033	Wilcox	High on top Wilcox
	Placid Oil Co.	Bentley Lbr. Co. No. 1	11	4 N	5 W	11/27/41	6,321	Wilcox	
Red River.....	Republic Prod. Co.	A. N. Timon Est. No. 1	39	11 N	9 W	10/ 7/41	6,303	Sligo	Lake End prospect
	J. L. Spier	M. J. House No. 1	11	14 N	11 W	2/28/41	1,768	U.Cre.	
	Thornton & La Croix	Prud. Life Ins. Co. No. 1	31	11 N	9 W	8/—/41	1,317	Nacatoch	Lake End prospect

TABLE 2.—(*Continued*)

Parish	Operator	Lease and Well Number	Location			Date Abandoned	Total Depth, Ft.	Abandoned in	Remarks
			Sec.	Twp.	Rge.				
Sabine	A. R. Chestnut	Thames No. 1	4	8 N	13 W	11/—/41	2,062	U.Cre.	2 mi. S. production in Converse
	Cryer Drill. Co.	Whitney Corp. No. 1	7	9 N	13 W	12/ 4/41	3,235	L.Cre.	1½ mi. W. production in Converse
	K. E. Merren	Nona Mills Co., Ltd. No. 1	28	3 N	12 W	6/ 7/41	4,039	Wilcox	
	B. F. Phillips	L. B. Blankenship No. 1	13	9 N	12 W	10/14/41	3,685	L.Cre.	Spring Ridge area; gas show 3216–3223 ft.
	Plummer & McDaniel	J. K. Phares No. 1	4	5 N	12 W	4/23/41	3,571	U.Cre.	Show 809–849 ft.
	J. E. Watts	Cook Land Co. No. 1	27	10 N	11 W	5/20/41	3,475	L.Cre.	
Tensas	H. L. Hunt	Ayer Tbr. Co. No. 2	18	13 N	11 E	1/14/41	4,550	Wilcox	
	H. L. Hunt	Chicago Mill & Lbr. Co. No. 5	1	11 N	9 E	9/16/41	4,396	Wilcox	
	A. Z. Phillips	Hollywood No. 1	22	12 N	12 E	12/18/41	6,515	U.Midway	
Union	Louark Prod. Co.	H. H. Farley, et al. Unit No. 1	10	20 N	1 W	5/28/41	5,104	L.Cre.	
	Tiki Exploration Co.	J. Jones Est. No. 1	30	21 N	3 W	4/23/41	3,770	L.Cre.	
Webster	H. L. Hunt	Pardee No. 1	36	22 N	10 W	1/ 3/41	6,105	Hosston	2 mi. N. of production at Cotton Valley
	W. G. Ray	Burson Unit No. 1	35	18 N	9 W	3/13/41	5,819	Rodessa	½ mi. N. production at Sibley and 200 ft. low on base Ferry Lake
W. Carroll	Crow Drill. Co.	E. L. Bruce No. 1	16	21 N	9 E	9/27/41	6,285	Jurassic	Well taken over by R. T. Thornton
Winn	Carter Oil Co.	Urania Lbr. Co. No. 1	31	12 N	1 E	12/31/41	3,435	U.Midway ?	
	H. L. Hunt	Goodpine No. F-2	13	9 N	3 W	8/27/41	4,668	Midway	
	H. L. Hunt	Goodpine No. F-3	26	10 N	2 W	10/—/41	3,136	Wilcox	
	H. L. Hunt	Goodpine No. F-8	29	10 N	1 W	9/ 4/41	3,844	Wilcox	
	H. L. Hunt	Goodpine No. F-9	9	10 N	2 W	9/ 4/41	3,861	Midway	
	H. L. Hunt	Goodpine No. F-11	35	10 N	3 W	11/17/41	3,980	Midway	
	H. L. Hunt	Goodpine No. F-13	19	11 N	4 W	12/20/41	5,337	L.Cre.	N. flank Coochie Brake dome
	Sells Petr. Co.	B. M. Feazell No. 1	26	13 N	3 W	5/23/41	4,498	Tokio	
	Nat. Wissman	Quinn Land Co. No. 1	23	9 N	6 W	7/24/41	2,618	Wilcox	

ently badly faulted, these dry holes have not, with certainty, defined the limits of the field.

The *Little Creek field,* a 1941 discovery in the same area, was extended approximately 2 miles to the northwest.

During the past year, 30 separate and distinct sands were found in various Wilcox fields in La Salle Parish. These sands, although fairly prolific, contain considerable amounts of salt water and are exceedingly difficult of completion. Some wells have been "squeezed" as many as four or five times.

Neale Field.—One of the more startling Wilcox discoveries in 1941 was the completion of two wells in the Neale field, Beauregard Parish, at a depth of approximately 2500 ft. below the top of the Wilcox. Two different sands were found. The effect of this discovery strongly indicates that production from below the top of the Wilcox may reasonably be expected anywhere from as far north as Caldwell Parish to as far south as Beauregard Parish, a downdip distance of at least 80 miles (Fig. 1).

Pine Prairie.—Although production was obtained approximately 10 years ago from over the top of the Pine Prairie dome, in Evangeline Parish, the new Cockfield production discovered in April 1941 on the east flank of the dome may be considered in the light of a new field. This field probably should be considered, from a geographical viewpoint, with south Louisiana. However, geologically it belongs with the so-called "Sparta-Wilcox trend," or, more precisely, with the "Conroe trend," thus linking it with central and north Louisiana. This field, a piercement type salt dome, will undoubtedly be erratic in development, as already indicated by various dry holes, but nevertheless very productive, since production probably will also be obtained from the Sparta and Wilcox formations.

Ajax and Grand Cane Fields.—Only two new Cretaceous fields were found in Louisiana during 1941: (1) The Ajax field, in Natchitoches and De Soto Parishes, which is productive from the Lower Cretaceous, and (2) the Grande Cane field, in De Soto Parish, which is productive from the Upper Cretaceous. Both of these fields are comparatively small discoveries, but such production suggests that exploratory wells in the Wilcox trend should be drilled down into the Cretaceous rather than stopped at the top of the Midway.

The *Logansport* gas field, in De Soto Parish, received a considerable stimulus in 1941 through a 2½-mile extension of the Jeter lime (Rodessa formation). The well that extended production had an open-flow potential of 170,000 M cu. ft., one of the largest recorded in the state.

The *Sugar Creek* field, in Claiborne Parish, was extended ¾ mile in a southwest direction by Hassie Hunt's William Deas No. 1 well. This well was completed in the top of the Hosston formation as the first oil well on the south flank of the Sugar Creek structure, at a depth of approximately 5750 feet.

Haynesville Field.—New Pettit lime (Sligo formation) production was encountered at a depth of 5000 ft. in the Haynesville field, Claiborne Parish. The discovery well was on the south flank. Similar production was also found in the central part of the field, at least 200 ft. higher than in the discovery well.

Lisbon Field.—The first Smackover lime production in Louisiana was found during 1941 in the Lisbon field, Claiborne Parish, about 2 miles north of the older producing area. The production is gas condensate. The gas probably can be used advantageously for repressuring the older producing sand in the area. Gas production was discovered also about 3 miles from the older production on the northeast flank of the Lisbon structure, in the upper part of the Hosston formation, at approximately 5100 ft. in depth.

WILDCAT WELLS

A total of 175 wildcat, or exploratory, wells were drilled in Louisiana during 1941. Thirty of these wells found new fields. Approximately 17 per cent, therefore, were successful.

Ninety-three wildcat wells were drilled in search of Wilcox production: 45 for production from the Miocene; 23 from the Lower Cretaceous; nine, from the Upper Cretaceous; three, from Cockfield and Sparta; two, from the Jurassic. It is evident from these figures that in south Louisiana the chief interest continued to be in Miocene sands associated with domal-type structures. In north Louisiana, the Wilcox attracted most of the interest, the Lower Cretaceous running a poor second.

Some of these wildcat wells encountered interesting "shows" and probably will encourage further drilling. Others were without any merit. Some of the wells encountering no oil or gas revealed encouraging structural information and probably will assist in developing future programs of exploration.

ACKNOWLEDGMENTS

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Oil and Gas Development in Michigan during 1941

By Theron Wasson,* Member A.I.M.E.

The discovery of two new fields—the Reed City area of Osceola County and the Headquarters field, of Roscommon County—and the important development in Winterfield township, Clare County, again demonstrate the fact that it is the unknown and unexpected that enter very definitely into the oil-producing history of Michigan. This is particularly true in the area of thick glacial drift in the north central part of the state, where the new prolific fields have been discovered this year. This shifts the interest from the southwestern part of the lower peninsula, where a number of pools were rapidly developed during 1939 and 1940, back into the Central Basin area.

As a result of strict proration in the new areas, the production for the state of Michigan for the year has not been as great as in 1940 or 1939. In 1941 the total production was 16,300,000 bbl., in 1940 it was 19,551,000 bbl., and in 1939, which was the peak year, it was 23,300,000 bbl. However, the discovery of the new fields this year nearly doubles the estimated reserves for Michigan reported at the end of 1940. In 1941 about 12,000,000 bbl. of oil was produced from the older fields, in which the individual well productions were so small that proration was not an important factor.

The total production for the state from the discovery of oil in 1925 through 1941 now stands at 161,205,000 barrels.

Active Oil Fields

Reed City Field.—In the Reed City field, Lincoln township, Osceola County, only small oil wells were completed during 1939 and 1940. The discovery of much larger production in wells drilled somewhat deeper, by The Pure Oil Co. and the Weber Oil Co., in the early part of 1941, led to the rapid development in this area. Some wells have had initial productions as high as 10,000 bbl. By the end of the year 111 producing wells were completed, with an average depth of 3600 ft., from the Detroit River formation of Devonian age. The entire development of the field to the end of 1941 was on 20-acre spacing.

Headquarters Field.—The Headquarters field, which lies along the line between Clare and Roscommon Counties, was one of the most important discoveries of 1941 and will be the scene of vigorous development during 1942. Production so far has been from the Traverse lime at about 3400 ft., and development has indicated that this is probably one of the most productive Traverse pools yet discovered. One well had been given a potential of 10,000 bbl. per day. Dry holes well located in relation to big producers indicate that it is a typical Traverse development.

Winterfield Field.—This field, in Winterfield township, Clare County, was discovered late in 1940. By December 1941, 14 Dundee and 5 Traverse producers had been completed. The Dundee lime is found at a depth of 3750 ft. and the Traverse lime at 3070 ft. Producing conditions in the Dundee seem to be erratic because of varying porosity in the dolomitized limestone.

Kawkawlin Field.—The Kawkawlin field, which was discovered by the Gulf Refining Co. in 1938, is in Monitor and Kawkawlin townships, Bay County. Small production

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has been obtained from the Berea at 1500 ft. and the Dundee at 2740 ft. Shows of oil have been obtained in deeper horizons in the Bateson No. 1, which was drilled to a total depth of 10,477 ft.

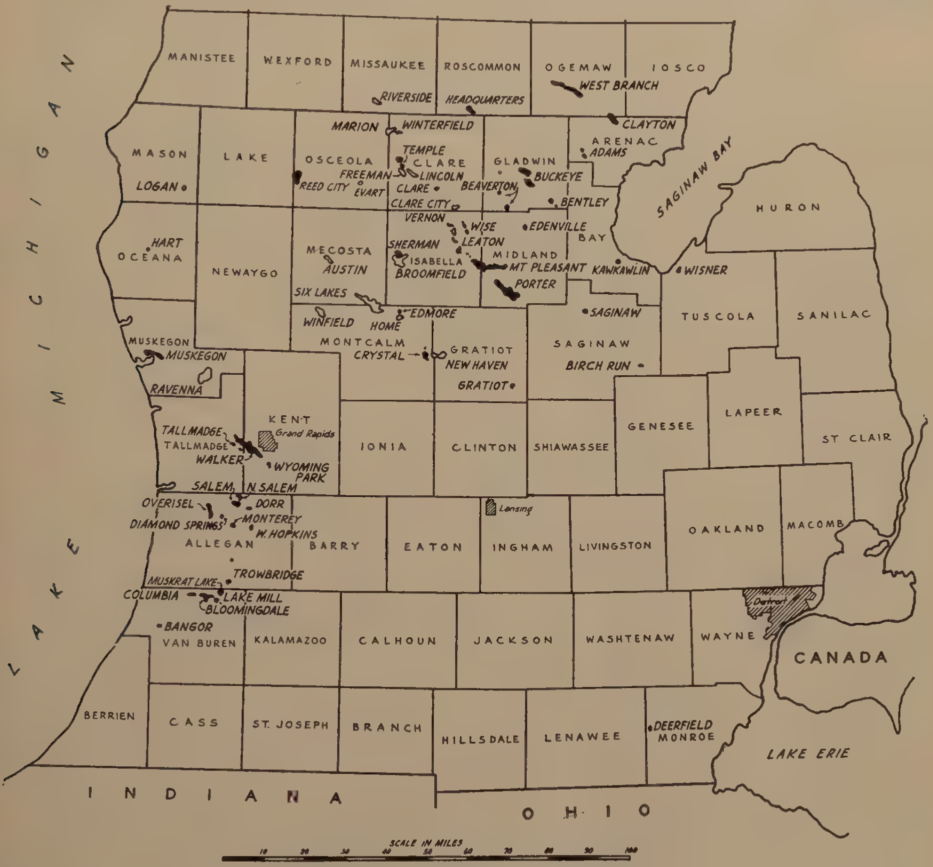

FIG. 1.—OIL AND GAS FIELDS OF MICHIGAN IN 1941.

Muskrat Lake Field.—Southwestern Michigan, during 1941, had considerable drilling activity, and the Muskrat Lake field, of Bloomingdale township, Van Buren County, was probably the most important area discovered. By the end of the year, 42 producing wells had been completed in this field, having a combined initial production of about 3000 bbl. Muskrat Lake is in an area of many small fields and further drilling will make it difficult to distinguish one field from the other.

ACTIVE GAS FIELDS

Drilling for shallow gas in the Stray sand to depths of about 1450 ft. continued in the Winterfield area of Clare County, where 29 gas wells were completed, and in the Reed City area, where 25 wells were completed. Gas development continued in Riverside township, Missaukee County. All drilling in these fields up to Dec. 23, 1941, was on the basis of one well to 160 acres. Previously discovered gas fields, such as Six Lakes field of Montcalm County and others, continued to produce but had very little new development.

WILDCAT DRILLING

The most important test of 1941 was the Gulf Bateson No. 1, in the Kawkawlin

TABLE 1.—*Oil and Gas Production in Michigan*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941		
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]
1	Adams, *Arenac*	1937	1,010	0	1,548,983	1,115,597	0	0	54	26	0	0	48	0
2	Akron-Wisner, *Tuscola*	1936	0	0	88,949	73,627	0	0	12	0	0	0	8	0
3	Austin, *Mecosta*	1935	0	2,200	0	0	5,758	102	29	0	2	0	0	12
4	Bangor, *Van Buren*	1939	240	0	295,075	122,953	0	0	18	2	1	0	13	0
5	Beaverton (North), *Gladwin*	1935	300	0	626,999	27,504	0	0	28	0	1	0	13	0
6	Beaverton (South), *Gladwin*	1935	300	0	231,203	120,424	0	0	16	9	0	0	16	0
7	Bentley, *Gladwin*	1937	1,000	0	637,250	99,479	0	0	40	2	1	0	36	0
8	Birch Run, *Saginaw*	1934	300	0	190,068	9,458	0	0	28	0	1	0	24	0
9	Bloomingdale Township, *Van Buren*	1938	2,950	0	5,895,684	722,108	0	0	243	54	21	0	156	0
10	Broomfield and Deerfield, *Isabella*	1930	0	4,100	0	0	6,935	569	60	6	1	0	0	40
11	Buckeye (North), *Gladwin*	1936	2,900	0	14,306,652	534,939	0	0	262	0	24	0	180	0
12	Buckeye (South), *Gladwin*	1936	2,500	0	3,687,874	128,581	0	0	188	0	6	0	88	0
13	Clare (gas), *Clare*	1929	0	400	0	0	712	16	9	0	0	0	0	6
14	Clare City, *Clare*	1938	20	640	16,938	5,652	1,045	131	7	0	0	0	2	7
15	Clayton, *Arenac*	1936	1,300	560	3,462,601	254,953	2,487	905	88	0	9	0	43	27
16	Columbia, *Van Buren*	1938	1,230	0	1,862,367	160,546	0	0	103	2	13	0	54	0
17	Crystal, *Montcalm*	1935	2,180	200	7,152,319	76,505	365	26	241	1	3	0	22	6
18	Deerfield, *Monroe and Lenawee*	1935	240	0	236,327	84,132	0	0	30	2	3	0	25	0
19	Diamond Springs, *Allegan*	1938	560	0	710,127	54,709	0	0	55	0	4	0	23	0
20	Dorr, *Allegan*	1938	360	0	264,124	23,044	0	0	26	2	2	0	18	0
21	Edmore, *Montcalm*	1933	160	0	419,149	14,820	0	0	13	0	1	0	5	0
22	Edenville, *Midland*	1938	400	0	1,094,166	64,900	0	0	35	0	0	0	26	0
23	Evart, *Osceola*	1941	0	*y*	0	0	*y*	*y*	2	2	0	0	0	2
24	Freeman, *Clare*	1938	0	1,760	0	0	896	510	14	0	0	0	0	13
25	Gratiot, *Gratiot*	1927	0	400	288	0	0	0	3	0	0	0	0	0
26	Hart, *Oceana*	1932	160	0	116,275	0	0	0	17	0	0	0	0	0
27	Headquarters, *Roscommon*	1941	840	0	314,740	314,740	0	0	10	10	0	0	10	0
28	Home, *Montcalm*	1938	0	5,000	0	0	2,518	1,106	24	0	2	0	0	21
29	Kawkawlin, *Bay*	1938	4,460	160	226,193	184,088	*y*	*y*	36	32	0	0	35	1
30	Leaton, *Isabella*	1929	2,100	480	2,880,976	130,163	185	0	92	2	1	0	45	1
31	Lincoln, *Clare*	1938	0	2,720	0	0	1,528	1,013	15	1	0	0	0	15
32	Marion-Winterfield, *Osceola and Clare*	1940	860	5,600	1,107,847	1,099,462	578	578	75	43	0	0	29	28
33	Monterey, *Allegan*	1938	300	0	354,334	31,896	0	0	28	0	1	0	18	0
34	Mt. Pleasant, *Isabella and Midland*	1928	8,000	0	21,522,015	385,152	0	0	444	2	9	0	183	0
35	Muskegon, *Muskegon*	1927	2,700	0	6,685,498	29,157	7,803	43	412	0	22	0	25	8
36	New Haven, *Gratiot*	1935	0	2,400	0	0	3,212	665	53	2	1	0	0	49
37	Overeisel, *Allegan*	1938	2,080	0	1,854,522	383,576	0	0	155	2	25	0	108	0
38	Porter-Yost, *Midland*	1931	8,440	0	38,192,021	1,543,371	0	0	536	5	7	0	333	0
39	Ravenna, *Muskegon*	1936	0	3,840	0	0	1,152	47	29	0	0	0	0	27
40	Reed City, *Osceola*	1941	3,500	4,470	2,755,252	2,753,335	439	439	138	134	0	0	112	25
41	Riverside, *Missaukee*	1940	0	3,000	0	0	124	124	9	5	0	0	0	9
42	Saginaw, *Saginaw*	1925	1,800	0	1,373,632	22,576	0	0	282	0	0	0	55	0
43	Salem, *Allegan*	1937	2,500	0	2,782,026	290,007	0	0	205	28	6	0	165	0
44	Salem (New), *Allegan*	1938	1,100	0	2,955,609	587,120	0	0	104	2	8	0	88	0
45	Sherman, *Isabella*	1936	1,220	0	3,899,647	287,867	0	0	96	1	2	0	61	0
46	Six Lakes, *Mecosta and Montcalm*	1934	0	10,120	0	0	26,637	4,848	246	2	3	0	0	194
47	Tallmadge (South), *Kent*	1939	560	0	208,978	172,219	0	0	58	33	1	0	52	0
48	Temple, *Clare*	1938	2,710	0	12,156,844	1,939,786	0	0	166	3	13	0	130	0
49	Vernon, *Isabella*	1930	1,100	880	4,295,037	159,593	1,394	35	93	2	3	0	34	5
50	Walker, *Kent*	1938	5,500	0	8,321,071	1,281,567	0	0	488	19	8	0	465	4
51	West Branch, *Ogemaw*	1933	5,000	0	4,556,559	405,646	0	0	257	0	3	0	232	0
52	West Hopkins, *Allegan*	1941	360	0	86,259	86,259	0	0	17	17	0	0	17	0
53	Winfield, *Montcalm*	1938	0	1,920	40,184	29,226	1,432	621	17	3	0	0	4	14
54	Wise, *Isabella*	1938	1,200	960	1,503,345	377,534	1,347	1,298	68	3	2	0	61	6
55	Wyoming Park, *Kent*	1939	450	0	88,721	21,924	0	0	21	0	3	0	12	0
56	Miscellaneous				579,750	202,635	4,075	1,669	118	86	17	0	60	40
57	Total		74,890	50,850	161,585,478	16,328,756	70,626	13,345	5,891	527	224	0	3,134	560

[b] Footnotes to column heads and explanation of symbols are given on page 250.

TABLE 1.—(*Continued*)

	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.			Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells											Depth, Avg. Ft.					
Line Number	Flowing	Artificial Lift	Initial	Avg. at End of 1941	Repressuring Operation[d]	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	19	29	*y*	*y*	0	37 34.3	*y* *y*	Traverse Dundee	Dev	L	P	2,031 2,841	2,039 2,921	15 16	A	Monroe	4,960
2	0	8	*y*	*y*	0	*y*	*y*	Dundee	Dev	L	P	2,840	2,860	5	A	Monroe	3,432
3	0	0	512	*y*	0	*x*	*x*	Stray, Marshall	Mis	S	P	1,390	1,410	10	A	Monroe	4,042
4	0	13	*y*	*y*	0	28.5	*y*	Traverse	Dev	L	P	1,002	1,006	2	A	Traverse	1,050
5	0	13	*y*	*y*	0	41.3	0.16	Dundee	Dev	L	P	3,880	3,895	12	A	Dundee	4,025
6	0	16	*y*	*y*	0	41.3	0.16	Dundee	Dev	L	P	3,880	3,895	12	A	Dundee	4,025
7	0	36	*y*	*y*	0	41.4	*y*	Dundee	Dev	L	P	3,500	3,536	25	A	Dundee	3,685
8	0	24	*y*	*y*	0	42.4	0.25	Berea	Mis	S	P	1,529	1,546	13	A	Dundee	2,760
9	0	156	*y*	*y*	0	41.2	0.51	Traverse	Dev	L	P	1,216 1,277	1,219 1,279	2.5 1.5	A	Monroe	1,904
10	0	0	580	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,300	1,350	5	A	Monroe	3,788
11	0	180	*y*	*y*	0	39	0.25	Dundee	Dev	L	P	3,621	3,647	11	A	Monroe	4,696
12	0	88	*y*	*y*	0	39	0.25	Dundee	Dev	L	P	3,574	3,597	11	A	Monroe	4,330
13	0	0	*y*	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,408	1,413	5	A	Monroe	4,055
14	0	2	605	*y*	0	30.5	0.40	Stray, Marshall	Mis	S	P	1,283	1,293	65	A	Monroe	3,865
15	0	43	620	*y*	0	34.3	*y*	Berea (gas) Dundee (oil)	Mis Dev	S L	P	1,166 2,534	1,189 2,576	12 12	A	Dundee	2,707
16	0	54	*y*	*y*	0	39.2	0.57	Traverse	Dev	L	P	1,190	1,193	2.5	A	Monroe	1,904
17	0	22	448	*y*	0	45.2	*y*	Stray, Marshall Monroe (oil)	Mis Dev	S L	P	1,016 3,191	1,024 3,202	4 4	A	Monroe	3,520
18	0	25	*y*	*y*	0	40	*y*	Trenton	Ord	L	P	2,102	2,114	9	MF	St. Peters	2,512
19	0	23	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,466	1,472	3.5	A	Traverse	1,571
20	0	18	*y*	*y*	0	41.4	0.44	Traverse	Dev	L	P	1,596	1,607	4	A	Monroe	2,065
21	0	5	900	*y*	0	43.2	0.11	Traverse	Dev	L	P	3,108	3,112	4	A	Monroe	3,700
22	0	26	*y*	*y*	0	41.3	*y*	Dundee	Dev	L	P	3,778	3,796	8	A	Dundee	4,015
23	0	0	*y*	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,395	1,467	15	*y*	Marshall	1,467
24	0	0	607	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,486	1,512	12	A	Monroe	3,956
25	0	0	*y*	*y*	0	*y*	*y*	Parma	Pen	S	P	500	510	10	A	Dundee	3,100
26	0	0	*x*	0	0	34.0	*y*	Traverse	Dev	L	P	1,880	1,890	4	A	Dundee	2,407
27	10	0	*y*	*y*	0	40.6	0.16	Traverse	Dev	L	P	3,285	3,453	5	A	Dundee	4,313
28	0	0	515	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,390	1,400	7.5	A	Monroe	3,665
29	0	35	*y*	*y*	0	34.9	0.37	Dundee	Dev	L	P	2,770	2,870	*y*	A	St. Peters	10,447
30	0	45	550	*y*	0	43	0.16	Stray, Marshall Dundee (oil)	Mis Dev	S L	P	1,239 3,634	1,243 3,681	4 7.5	A	Monroe	4,390
31	0	0	607	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,526	1,538	10	A	Monroe	4,285
32	15	14	*y*	*y*	0	44	0.50	Stray, Marshall Traverse Dundee	Mis Dev	S L L	P	1,392 3,140 3,743	1,408 3,156 3,770	9 5 3	A	Monroe	3,945
33	0	18	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,638	1,647	3	A	Traverse	1,808
34	0	183	*y*	*y*	0	41.5	0.13	Dundee	Dev	L	P	3,536	3,568	14.6	A	Sylvania	4,821
35	0	25	*y*	*y*	0	37.4	0.56	Traverse, Dundee	Dev	L	P	2,050	2,075	10	A	St. Peters	4,754
36	0	0	448	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	915	950	5	A	Dundee	3,657
37	0	108	*y*	*y*	0	39.4	0.50	Traverse	Dev	L	P	1,471	1,481	3	A	Traverse	1,690
38	0	333	*y*	*y*	0	41.3	0.26	Dundee	Dev	L	P	3,422	3,434	12	A	Sylvania	4,732
39	0	0	720	*y*	0	0	*y*	Berea	Mis	S-D	P	1,212	1,233	10	*y*	Dundee	2,306
40	106	6	1,418	1,315–1,385	0	45	0.596	Traverse Dundee Monroe	Dev	L,D	P	2,935 3,492 3,540	2,945 3,518 3,592	5 5 3	A	Monroe	3,648
41	0	0	*y*	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,331	1,355	15.7	A	Monroe	3,945
42	0	55	*y*	*y*	0	44.3	0.24	Berea	Mis	S	P	1,820	1,850	16	A	Sylvania	3,970
43	0	165	*y*	*y*	0	41	0.60	Traverse	Dev	L	P	1,587	1,601	8	A	Dundee	1,950
44	0	88	*y*	*y*	0	41	0.56	Traverse	Dev	L	P	1,621	1,631	6	A	Monroe	1,968
45	0	61	*y*	*y*	0	47.8	*y*	Monroe	Dev	L	P	3,648	3,652	4	A	Monroe	4,031
46	0	0	516	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,275	1,300	16	A	Monroe	3,529
47	0	52	*y*	*y*	0	42	*y*	Traverse	Dev	L	P	1,820	1,845	7.5	A	Traverse	1,936
48	0	130	*y*	*y*	0	43.8	0.37	Monroe	Dev	D	P	3,895	3,900	4.5	A	Monroe	3,945
49	0	34	575	*x*	0	44.1	0.30	Monroe	Dev	D	P	3,741	3,743	3	A	Monroe	3,907
50	0	465	*y*	*y*	0	42.1	0.42	Traverse	Dev	L	P	1,827	1,847	6	A	Monroe	2,400
51	0	232	*y*	*y*	0	33.4	0.35	Traverse Dundee	Dev	L	P	1,880 2,622	1,910 2,707	5 20	A	Monroe	3,637
52	0	17	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,587	1,598	2	A	Traverse	1,634
53	0	4	446	*y*	0	0	*y*	Stray, Marshall	Mis	S	P	1,124	1,141	8	A	Monroe	3,374
54	0	61	*y*	*y*	0	47	*y*	Dundee	Dev	L	P	3,702	3,716	10.5	A	Dundee	3,723
55	0	12	*y*	*y*	0	*y*	*y*	Traverse	Dev	L	P	1,191	1,218	6	A	Traverse	2,102
56	0	60			0												
57	150	2,984															

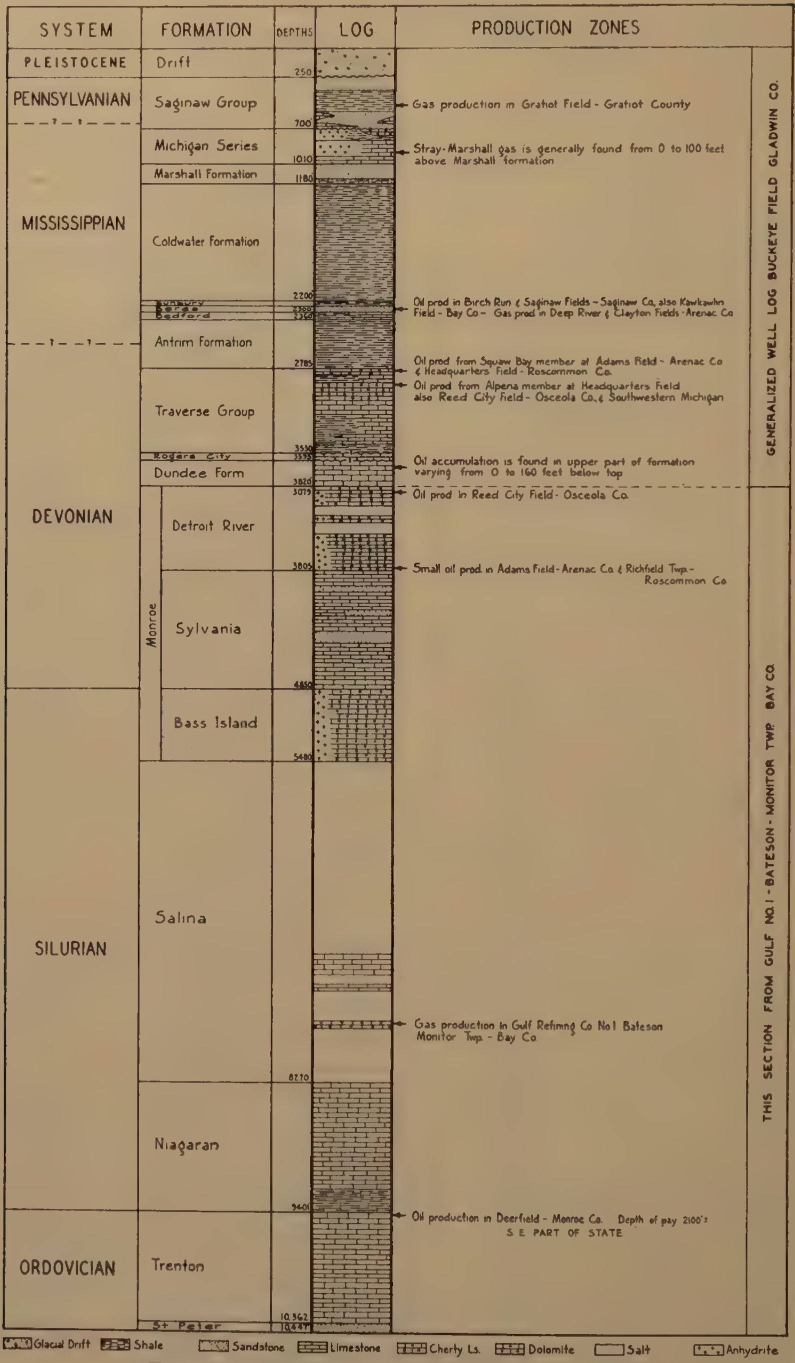
SYSTEM
FORMATION
DEPTHS
LOG
PRODUCTION ZONES
PLEISTOCENE
Drift
250
PENNSYLVANIAN
Saginaw Group
700
Gas production in Gratiot Field - Gratiot County
MISSISSIPPIAN
Michigan Series
1010
Stray-Marshall gas is generally found from 0 to 100 feet above Marshall formation
Marshall Formation
1180
Coldwater Formation
2200
Sunbury
Berea
Bedford
2300
2360
Oil prod in Birch Run & Saginaw Fields - Saginaw Co, also Kawkawlin Field - Bay Co - Gas prod in Deep River & Clayton Fields - Arenac Co
Antrim Formation
2785
Oil prod from Squaw Bay member at Adams Field - Arenac Co & Headquarters Field - Roscommon Co.
Oil prod from Alpena member at Headquarters Field also Reed City Field - Osceola Co. & Southwestern Michigan
DEVONIAN
Traverse Group
3530
Rogers City
3595
Dundee Form
Oil accumulation is found in upper part of formation varying from 0 to 160 feet below top
3826
3079
Oil prod in Reed City Field - Osceola Co.
Monroe
Detroit River
3805
Small oil prod in Adams Field - Arenac Co & Richfield Twp - Roscommon Co
Sylvania
4850
Bass Island
5480
SILURIAN
Salina
Gas production in Gulf Refining Co No 1 Bateson Monitor Twp - Bay Co
8270
Niagaran
9401
ORDOVICIAN
Trenton
Oil production in Deerfield - Monroe Co. Depth of pay 2100'±
S. E. PART OF STATE
10,362
St Peter
10,447
GENERALIZED WELL LOG BUCKEYE FIELD GLADWIN CO.
THIS SECTION FROM GULF No 1 - BATESON - MONITOR TWP. BAY CO.
Glacial Drift
Shale
Sandstone
Limestone
Cherty Ls.
Dolomite
Salt
Anhydrite

FIG. 2.—PRODUCTION ZONES IN MICHIGAN IN 1941.

field, which was drilled to a total depth of 10,477 ft. It showed salt water in the St. Peter sandstone and was plugged back to a shallower horizon near the base of the Salina, where a gas well was made at a depth of 7760 ft. This test, near the middle of the Michigan Basin, gives for the first time an accurate measurement of the stratigraphic section from the glacial drift of Pleistocene age to the St. Peter of Ordovician age. Another important deep test is the Producers Committee's George Riddering No. 1, in the Grand Rapids field, which has reached the St. Peter at a

TABLE 2.—*Summary of Drilling Operations in Michigan*

Important Wildcats Drilled in 1941
Surface Formation, Pleistocene

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Allegan.......	18	3 N	12 W	1,573	Traverse	C. Perry	200		Discovery well in West Hopkins field
2	Arenac.......	21	19 N	3 E	4,629	Detroit River	D. Rayburn	16		Indicates possible commercial production from Detroit River rocks in area
3	Bay..........	2	14 N	4 E	10,447	St. Peters	Gulf Refining Co.		8.5	Deepest well ever drilled in Michigan. First well in basin to test St. Peters sandstone
4	Berrien.......	34	3 S	17 W	2,502	Trenton	J. Warman			Trenton test giving new stratigraphic data on deeper measures
5	Calhoun......	15	3 S	4 W	1,609	Traverse	Continental Oil Co.		10.5	Indicates new possibilities for southern part of Michigan
6	Cass.........	15	8 S	15 W	2,312	Trenton	R. Tamblyn			Trenton test giving new stratigraphic data on deeper measures
7	Clare.........	16	19 N	3 W	5,400	Sylvania	Sun Oil Co.			First Sylvania test in Clare County
8	Clare.........	15	19 N	3 W	1,278	Marshall	Sun Oil Co.		23	Gas discovery. Should lead to additional development in 1942
9	Clinton.......	14	5 N	3 W	5,363	Niagaran	Saba Oil & Dev. Co.			Niagaran test giving new stratigraphic data on deeper measures
10	Huron........	8	17 N	14 E	3,422	Detroit River	W. Markle			Large showing of oil in Lower Detroit River formation giving further evidence of possible commercial production from this zone
11	Mason........	9	17 N	15 W	3,303	Sylvania	Merrill & Dean		0.13	Good showing of gas in Sylvania sandstone
12	Oceana.......	8	16 N	16 W	3,507	Salina	American Drill. Co.			First Salina test in Oceana County
13	Osceola.......	22	18 N	8 W	1,467	Stray	Taggart Bros.		0.38	Gas discovery. Should lead to additional development in 1942
14	Roscommon...	34	21 N	3 W	3,438	Traverse	E. Hilliard	10,000		Discovery well in Headquarters field
15	Roscommon...	29	24 N	1 W	4,209	Detroit River	Sun Oil Co.	80		Produced from zone 1027 ft. below top Detroit River

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1941....................................	66	20
Number of oil wells completed during 1941................................	420	13
Number of gas wells completed during 1941...............................	85	9
Number of dry holes completed during 1941................................	135	276

depth of 5161 ft. This test is an important contribution to the stratigraphy of the southwestern part of the state.

Exploration

Exploration by shallow drilling for structural information on beds below the glacial drift continued throughout the year. Some reflection seismograph work of an experimental nature was done in several of the oil-producing counties. While results of this are not generally known, it did not lead to leasing on any large scale and, so far, no major oil field in Michigan has been discovered by geophysical methods. The glacial drift, which is spread like a blanket over the oil-producing areas, and ranges from 100 to 1000 ft. in thickness, has been a handicap to geologists and geophysicists.

Drilling Methods

The rapid development in the Reed City and Headquarters fields has been made possible by the use of the rotary or by combination rotary and cable tools. The Gulf Refining Co. in the Reed City field was the first in Michigan to drill into the pay section with the rotary. Drilling in the older areas is still done with cable tools.

Proration

All the new fields discovered this year have been under strict proration since discovery. Reed City was allowed 480 bbl. per well per day from June to October and this was gradually reduced to 200 bbl. per well per day by the end of the year. Headquarters and Winterfield fields were allowed 350 bbl. per well per day at the end of the year. The Adams field, Arenac County, operated under voluntary proration of 150 bbl. per well per day during most of the year.

Prices

Michigan has seen a gradual increase in price for all areas during the year. The crude oil from the old pools of Midland County, which at the beginning of the year was quoted at $1.22, is now posted at $1.44 per barrel. The Sherman grade oil of Temple, Freeman, Reed City, and Winterfield, which in January 1941 was $1.17, has been raised to $1.39 per barrel. Increases in other areas were proportional to Midland and Sherman.

Acknowledgments

Mr. Carl C. Addison, Division Geologist of The Pure Oil Co. at Saginaw, Mich., and Mr. D. C. Shackelford, Chief Scout of that company, assisted in the preparation of this report. As in the past, the State Geological Survey of Michigan has furnished information on oil and gas production.

Oil and Gas Development in Mississippi during 1941

By H. M. Morse*

Mississippi, during the year 1941, experienced the greatest diversity of oil activity since the beginning of oil interest in the state—core tests for exploration, core tests for sulphur, continued drilling at Tinsley for production, and wildcatting, which brought to light two new oil fields and two new salt domes. There were 45 wildcat wells drilled in 1941, which showed greater results and findings geologically than the 85 drilled in 1940.

Tinsley Oil Field (*Yazoo County*).—The Tinsley oil field, with its boundaries fairly well defined now, is 8 miles long and 3 miles wide at its widest point. During the past year 213 producing wells were completed, which brought the total number of producers in the field by the end of 1941 to 325 wells. Seven producing sands have been logged, with a total average thickness of 30 ft. of oil sand. The producing formations are the Selma, Eutaw and Tuscaloosa. The average total depth of the wells is 5012 ft. The average gravity of the oil is 35.4°. Production for 1941 was approximately 15,500,000 bbl. of oil.

Vaughan-Pickens Oil Field (*Yazoo County*).—At the end of 1941 only three wells were producing in this field, the fourth having been abandoned. The total production for the field for the year was approximately 250,000 bbl. of oil. The producing sand is the Wilburn, in the Eutaw formation.

Cary Field (*Sharkey County*).—The British American Oil Producing Co. completed, on Sept. 1, 1941, its F. B. Houston No. A-1 well, sec. 23, T. 11 N., R. 7 W. It is

Table 1.—*Oil and Gas Production in Mississippi*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
										During 1941		End of 1941			Number of Wells	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
1	Jackson gas field, *Hinds and Rankin*	1930		7,500			110,376	3,878	217	6	2	0	0	23		
2	Pickens-Sharpsburg oil field, *Madison*	1941	40		7 753	7,753			1	1	0	0	1	0	1	0
3	Cary oil field, *Sharkey*	1941	40		3,578	3,578			2	1	1	0	1	0	0	1
4	Tinsley oil field, *Yazoo*	1939	9,840		19,602,264	15,277,273			349	214	19	0	324		3	321
5	Vaughan-Pickens oil field, *Yazoo*	1940	40		496,253	209,997			9	0	1	0	3			3
6	Total		9,960	7,500			110,376	3,878	578	222	13	0	329	23	4	325

[b] Footnotes to column heads and explanation of symbols are given on page 250.

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* State Oil and Gas Supervisor, Jackson, Miss.

producing from the Selma chalk. The gravity of the oil is 27°.

Pickens-Sharpsburg Oil Field (Madison County).—On Dec. 4, 1941, the discovery well of the Pickens-Sharpsburg field, Buzz Morgan's Johnny No. 1, sec. 4, T. 11 N., R. 3 E., was completed. This well produces from the Wilburn sand in the Eutaw. The gravity of the oil is 40.8°. The Phillips Petroleum and Carter Oil companies are expected to do further drilling in this area in the early part of 1942. In December the production for this well was 7753 bbl. of oil.

Core Tests.—The Carter Oil Co. and The Sun Oil Co. drilled several core holes for exploration purposes. The Freeport Sulphur Co. drilled a series of 9 core holes for sulphur on the Tatum salt dome, Lamar County. Another series of core tests will be drilled by them during 1942.

Salt Domes.—During 1942 two new salt domes were discovered, one in Warren County and one in Hinds County.

Prospects for 1942.—Mississippi probably will have from 40 to 50 wildcat wells drilled during 1942, with approximately 100 wells drilled in various oil fields throughout the state. In view of the oil showings in wells drilled in Mississippi during 1941, Mississippi may expect new fields to be developed this year.

TABLE 1.—(*Continued*)

	Reservoir Pressure, Lb. per Sq. In.			Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
										Depth, Avg. Ft.					
Line Number	Initial	Avg. at End of 1941	Repressuring Operation[d]	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	1,010	860				Selma	CreU	C		2,420	2,435	15	MI	Trinity-CreL	5,529
2	110	110		39.9		Eutaw	CreU	S	x	4,824	4,833	66[1]	A	Tuscaloosa-CreU	5,658
3	0	0		24.8	x	Selma	CreU	C	x	3,278	3,283	5	x	Igneous-Cre	4,355
4				33.9	x	Selma Eutaw Tuscaloosa	CreU	S	x	4,378	5,834	153–254[2]	Faulted dome	Tuscaloosa-CreU	6,540
5	0	0		39.9	x	Eutaw	CreU	S	x	4,865	4,871	6	AF	Tuscaloosa-CreU	6,043
6															

[1] Sand 66 ft., producing only 9 ft.

[2] Average producing section 30 ft.

TABLE 2.—*Summary of Drilling Operations in Mississippi*

Wildcats Drilled in 1941

	County	Operator, Well and Number	Location	Total Depth, Ft.	Bottom-hole Formation
1	Adams	L. H. Simpson, Fairchild Pltg. No. 1	SE SE sec. 18, T 9 N, R 2 W	6,015	Wilcox
2	Attala	Clint Crosby, J. F. Allen No. 1	SE SE sec. 33, T 13 N, R 5 E	4,534	Tuscaloosa
3	Bolivar	Ed S. Holman, E. K. Thomas No. 1	SE NE NE sec. 18, T 24 N, R 7 W	4,664	Bendian
4	Clarke	Walsingham & Earles, School Land No. 1	SW NW NE sec. 16, T 4 N, R 15 E	4,057	Tuscaloosa
5	Copiah	Sun Oil Co., J. G. Ainsworth No. 1	N½ NW SE sec. 17, T 9 N, R 7 E	9,792	Tuscaloosa
6	Forrest	Fohs Oil Co., Batson-Hatten No. 1	E½ NW SE sec. 10, T 1 S, R 12 W	8,752	Paluxy
7	Grenada	James Papadakis, Ed Holcomb No. 1	SE NE sec. 13, T 22 N, R 2 E	3,797	Tuscaloosa
8	Grenada	Womble & Williams, Conn. Gen. Life Ins. Co. No. 1	NE NW SE sec. 28, T 23 N, R 5 E	3,735	Pottsville
9	Hinds	Hassie Hunt, M. Montgomery No. 1	NW SW sec. 12, T 5 N, R 4 W	4,566	Wilcox
10	Hinds	Plains Production Co., Halifax Plantation No. 1[1]	NE SW NW sec. 1, T 7 N, R 4 W	3,999	Caprock
11	Issaquena	E. C. Johnston (W. G. Ray) Irby Charping No. 1	NE NW sec. 29, T 10 N, R 8 W	5,650	Glen Rose
12	Issaquena	Gholson & Bohon, C. M. Aden No. 1	NW NE sec. 31, T 9 N, R 6 W	6,050	Tuscaloosa
13	Jones	Turman N. Smith, J. A. Hollifield No. 1	NW SW NW sec. 20, T 8 N, R 12 W	6,338	Selma
14	Kemper	R. M. Crabb, W. A. Land No. 1	NW NW NE sec. 12, T 10 N, R 14 E	2,102	Eutaw
15	Kemper	A. E. Manning, J. W. McKelvaine No. 1	SE SE NE sec. 2, T 9 N, R 17 E	1,475	Eutaw
16	Lauderdale	Magnolia Petroleum Co., C. Culpepper No. 1	SW SW NE sec. 4, T 8 N, R 14 E	6,256	Pennsylvanian
17	Lauderdale	Pierce Watters et al., A. L. Meeds No. 1	W½ SW sec. 26, T 5 N, R 15 E	4,822	Paluxy
18	Lawrence	Tide Water Assoc. Oil Co., Denkmann Lbr. Co. No. 1	N½ N½ SW sec. 5, T 5 N, R 11 E	10,808	Tuscaloosa
19	Lawrence	Tide Water Assoc. Oil Co., Denkmann Lbr. Co. No. 2	NW NE sec. 29, T 5 N, R 11 E	6,642	Wilcox
20	Leake	Sinclair Wyoming Oil Co., Community Pearl River No. 1	NW SE NW sec. 28, T 9 N, R 6 E	9,007	Glen Rose
21	Leake	R. W. Williams et al., Grant Allen No. 1	NW SE sec. 26, T 12 N, R 7 E	5,028	Paluxy
22	Lee	R. L. Shoemaker, Martin No. 1	SE NE NW sec. 33, T 9 S, R 6 E	952	Mississippian
23	Madison	C. L. Morgan,[2] John Whitworth No. 1	NE SW sec. 4, T 11 N, R 3 E	5,658	Tuscaloosa
24	Madison	Sinclair Wyoming Oil Co., C. L. Harris No. 1	E½ NW sec. 26, T 10 N, R 5 E	6,011	Tuscaloosa
25	Marshall	C. B. Blosser, C. Stansback No. 1	SE SE sec. 19, T 3 S, R 4 W	655	Wilcox (?)
26	Marshall	P. J. Lunati, Fee No. 1	SW SE sec. 31, T 3 S, R 1 W	1,130	Ripley (?)
27	Montgomery	Henderson Oil Co., Mutual Life Ins. Co. No. 1	SE SE NW sec. 36, T 21 N, R 5 E	4,458	Paluxy (?)
28	Montgomery	Henderson Oil Co., School Land No. 1	SE NE NW sec. 16, T 19 N, R 6 E	4,280	Paluxy (?)
29	Noxubee	C. L. Thompson & A. C. Hope, H. N. Donahoo No. 1	NW sec. 25, T 16 N, R 17 E	2,871	Pennsylvanian
30	Prentiss	Home Development Co., A. Allen No. 1	NE NE SE sec. 8, T 7 S, R 9 E	2,145	Knox
31	Sharkey	British American Oil Prod. Co., F. B. Houston No. 1	N½ NE SW sec. 23, T 11 N, R 7 W	4,027	Tuscaloosa
32	Sharkey	British American Oil Prod. Co.,[3] F. B. Houston No. A-1	N½ NE SW sec. 23, T 11 N, R 7 W	4,355	Igneous
33	Stone	Danciger Oil Ref., Inc., School Land No. 1	SE SW sec. 16, T 2 S, R 11 W	8,522	Lower Tuscaloosa
34	Stone	Harry I. Morgan, Dantzler Lbr. Co. No. 2	NE SE sec. 4, T 4 S, R 10 W	8,506	Lower Tuscaloosa
35	Stone	Harry I. Morgan, University of Miss. No. 1	SW sec. 35, T 3 S, R 10 W	8,505	Lower Tuscaloosa
36	Tishomingo	F. F. Mellen & R. Gear, E. K. Wood No. 1	NW SE SE sec. 21, T 4 S, R 11 E	1,845	Knox
37	Warren	Magnolia Petroleum Co.,[4] J. H. Hall No. 1	NE NW NE sec. 39, T 17 N, R 4 E	4,176	Salt
38	Warren	Magnolia Petroleum Co., J. H. Hall No. 2	SW SE NE sec. 39, T 17 N, R 4 E	3,856	Cap Rock
39	Warren	Placid Oil Co., Anderson Tully No. 1	NE SW sec. 36, T 17 N, R 5 E	5,025	Wilcox
40	Warren	Waggoner Bros. Oil Co., R. L. Parker, Jr. No. 1	NW NW sec. 17, T 14 N, R 1 E	7,013	Selma
41	Wilkinson	Bering Oil Co., Crosby Lbr. Co. No. 1	SW SW SW sec. 15, T 4 N, R 2 W	5,601	Wilcox
42	Winston	Fraim & Young, H. C. Chancellor No. 1	SW SE sec. 9, T 13 N, R 14 E	350	Midway
43	Yalobusha	J. E. Green, W. Goldman No. 1	SW SE NW sec. 23, T 25 N, R 6 E	2,400	Tuscaloosa
44	Yazoo	Fred Endom et al., School Land No. 1	NE NE NE sec. 16, T 9 N, R 3 W	5,633	Selma
45	Yazoo	K. Hughes et al., G. C. Woodruff No. 1	NE SE sec. 19, T 11 N, R 2 W	6,543	Eutaw
46	Yazoo	E. C. Johnston, J. M. Gaddis No. 1	E½ sec. 26, T 10 N, R 1 W	6,021	Eutaw
47	Yazoo	Hunter Jones et al., W. M. Link No. 1	NE SE sec. 36, T 9 N, R 3 W	6,034	Selma
48	Yazoo	Sinclair Wyoming Oil Co., C. C. Swayze No. 1	W½ E½ W½ sec. 23, T 12 N, R 1 E	7,074	Tuscaloosa
49	Yazoo	Texas Pacific Coal & Oil Co., J. S. Allgood No. 1	NW NW sec. 10, T 11 N, R 2 W	6,865	Tuscaloosa

[1] Discovery Halifax salt dome.
[2] Discovery of Pickens-Sharpsburg oil field.
[3] Discovery of Cary oil field.
[4] Discovery of Kings salt dome.

Development of Oil and Gas in Missouri in 1941

By Frank C. Greene*

The year 1941 was uneventful in oil and gas development in Missouri. No new pools were opened and several areas with promising structures, in the northwestern part of the state, were disappointing when drilled. In looking for an explanation of these failures, it is suggested that it will be necessary to find areas in which the lower beds of the Mississippian are upfolded, in order to obtain production in northwestern Missouri. To do this, geophysical exploration or test drilling far enough into the Mississippian beds to get cores or cuttings of definitely established age appear to be the best methods.

Although not leading to new production, drilling in Missouri established two new state records, one for depth and another for the amount of rotary drilling. An important well† in sec. 24, T. 19 N., R. 11 E., Pemiscot County, in the southeastern corner of the state, was drilled with a rotary to 4740 ft., several hundred feet deeper than any previous hole. The total footage drilled by rotary rigs of various types was 31,135 ft. and that by cable tools, 29,166 feet.

The total number of completions was 85, of which 18 were gas wells with an initial open-flow capacity of 12,528,000 cu. ft., and 67 were dry holes. Of the latter, 19 were drilled into Mississippian or older formations.

Table 1 gives a summary of activities by counties.

Table 1.—*Wells Drilled for Oil and Gas in Missouri in* 1941

County	Number of Gas Wells	Gas Production, Cu. Ft.	Dry
Atchison			2
Bates			1
Buchanan			1
Caldwell	9	4,429,000	12
Cass			7
Clinton			3
DeKalb			4
Holt			3
Jackson	4	240,000	9
Knox			5
New Madrid			2
Pemiscot			2
Platte	5	7,859,000	10
Ray			3
St. Clair			1
Vernon			2
Totals	18	12,528,000	67

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* Geologist, Missouri Geological Survey, Rolla, Mo.

† Strake Petroleum Company's No. 1 T. Russell. Surface elevation, 266 ft.; base Eocene Wilcox, 1200 ft.; top Eocene Midway, 1200 ft.; top Cretaceous, 1634 ft.; top Paleozoic, 2060 ft.; total depth, 4740 ft.

Petroleum Development in Nebraska in 1941

By E. C. Reed*

NINETY wells were completed in Nebraska during 1941, of which 42 were producers. One of them was the discovery well of a new field. All of the production to date is in Richardson County. At the close of the year 14 wells were drilling and three more were shut down for orders, hoping for future development of production.

Most of the drilling activity was in Richardson County, which had 68 operations; 10 wells were drilled in Nemaha County, 5 drilled or drilling in Gage County, 3 each in Otoe and Furnas Counties, 2 each in Cass, Harlan, Johnson and Sarpy Counties, and 10 wells were completed or drilling over the remainder of the state.

The most important development of the year was the discovery in October of the Barada field, sec. 36, T. 3 N., R. 16 E.,

TABLE 1.—*Oil and Gas Production in Nebraska*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres: Oil	Total Oil Production, Bbl.: To End of 1941	Total Oil Production, Bbl.: During 1941	Total Gas Production, Millions Cu. Ft.: To End of 1941	Total Gas Production, Millions Cu. Ft.: During 1941	Number of Oil and/or Gas Wells: Completed to End of 1941	During 1941: Completed	During 1941: Abandoned	End of 1941: Temporarily Shut Down	End of 1941: Producing Oil[e]	End of 1941: Producing Gas[e]
1	Barada, *Richardson*...........	1941	120	34,400	34,400	None		6	6	0	0	6	0
2	Dawson, *Richardson*...........	1940	40	3,800	2,400	None		2	1	0	0	2	0
3	Falls City, *Richardson*.........	1939	1,062	2,048,150	1,775,300	None		55	27	2	0	53	0
4	Shubert, *Richardson*...........	1940	400	77,100	74,820	None		10	9	1	0	9	0
5	Total........................		1,622	2,197,650	1,886,920	None	None	73	43	3	0	70	0

Line Number	Oil-production Methods, End of 1941: Number of Wells: Flowing	Artificial Lift	Reservoir Pressure, Lb. per Sq. In.: Initial	Avg. at End of 1941	Character of Oil: Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Producing Formation: Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.: Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Deepest Zone Tested to End of 1941: Name	Depth of Hole, Ft.
1	0	6			29.6	?	Hunton	Dev	D	Cav	2,387	2,450	63	A	Hunton	2,517
2	0	2			21.7	?	Hunton	Dev	D	Cav	2,238	2,253	15	A	Granite (during 1937)	3,424
3	0	53	y	y	31.5	0.37	Hunton	Dev	D	Cav	2,250	2,273	23	A	Arbuckle	3,372
4	0	9	y	y	31	?	Hunton	Dev	D	Cav	2,495	2,518	23	N-T	Hunton	2,638
5	0	70														

[e] Footnotes to column heads and explanation of symbols are given on page 250.

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TABLE 2.—*Summary of Drilling Operations in Nebraska*

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
1	Cass	SE SE 8	11 N	13 E	1,352	Pleistocene on Pennsylvanian	Pre-Cambrian	Goldenrod Oil Co.			Dry and abandoned
2	Cass	NE NW 20	11 N	13 E	1,174	Pleistocene on Pennsylvanian	Maquoketa	Goldenrod Oil Co.			Abandoned—mechanical diff.
3	Dawes	NW SW 1	33 N	50 W		Cretaceous (Pierre)	Permian	Chadron Oil & Gas Co.			Drilling
4	Dawson	NW SE 21	10 N	22 W	3,371	Peistocene on Tertiary (Ogallala)	Pre-Cambrian	Phillips Petr. Co.			Dry and abandoned
5	Fillmore	NE NE 22	5 N	1 W	3,800	Pleistocene on Cretaceous (Greenhorn)	Pre-Cambrian	Will Ebke et al.			Dry and abandoned
6	Furnas	SE SW 28	1 N	22 W	3,652	Pleistocene on Cretaceous (Niobrara)	Pre-Cambrian	Morrison & Noah			Dry and abandoned
7	Furnas	SW SW 8	1 N	23 W	3,492		Pre-Cambrian	Barnsdall-Helmerich & Payne			Dry and abandoned
8	Furnas	C SE 14	3 N	23 W	3,565		Pre-Cambrian	Skelly-Helmerich & Payne			Dry and abandoned
9	Gage	NW SW 16	3 N	5 E	785	Pleistocene on Cretaceous (Dakota)	Permian	Bee-Dee Oil Co.			Dry and abandoned
10	Gage	NE NE 21	3 N	5 E	2,845	Pleistocene on Cretaceous (Dakota)	Pre-Cambrian	Williams & Rider			Shut down for orders
11	Gage	NE SW 15	3 N	6 E	265	Pleistocene on Permian	Permian	C. A. Nuttle et al.			Drilling suspended
12	Gage	NE SW 5	3 N	7 E	1,012	Pleistocene on Permian		Nelson Bros.			Drilling
13	Gage	SW SW 2	4 N	6 E	956	Pleistocene on Permian		S. F. Miller et al.			Drilling
14	Harlan	SW NW 15	1 N	18 W	4,211		Arbuckle	Hudson & Veeder			Shut down for orders
15	Harlan	SE NW 15	2 N	18 W	4,200		Arbuckle	Hudson & Veeder			Shut down for orders
16	Johnson	NW NW 17	4 N	12 E				Hays Drilling Co.			Spudded and shut down
17	Johnson	NE NW 29	6 N	10 E	350	Pleistocene	Pleistocene	Stone-Anderson Co.			Drilling occasionally
18	Keith	NW NW 26	14 N	37 W		Pleistocene on Tertiary (Ogallala)	Cretaceous	Double "O" Oil Co.			Drilling
19	Lancaster	SW SW 5	7 N	7 E	1,779	Pleistocene on Permian	Viola	August Krueger			Dry and abandoned
20	Lincoln	C NW 26	11 N	34 W	4,839	Pleistocene on Tertiary	Pre-Cambrian	Falcon-Seaboard			Dry and abandoned
21	Morrill	SE SE 10	23 N	49 W	4,683	Pleistocene on Tertiary (Ogallala)	Permian	Nebraska Oil Co.			Drilling suspended
22	Nemaha	NE NE 9	4 N	14 E	2,743	Pleistocene on Permian	Hunton	Frank Engles et al.			Dry and abandoned
23	Nemaha	SW NE 24	4 N	14 E	2,931	Pleistocene on Permian	Hunton	Phillips Petr. Co.			Dry and abandoned
24	Nemaha	SW NW 32	4 N	16 E	2,650	Pleistocene on Permian	Hunton	Blackgold Operating Co.			Dry and abandoned
25	Nemaha	SE NE 35	4 N	16 E	3,770	Pleistocene on Permian	Arbuckle	Francis Krone and Skelly Oil Co.			Dry and abandoned
26	Nemaha	SE SE 4	5 N	13 E	2,425	Pleistocene on Permian	Hunton	Kees et al.			Dry and abandoned
27	Nemaha	NW NE 7	5 N	13 E	3,306	Pleistocene on Permian	Pre-Cambrian	Palensky Bros. et al.			Dry and abandoned
28	Nemaha	NE SW 20	5 N	14 E	2,418	Permian	Hunton	Bow & Arrow Oil Co.			Dry and abandoned
29	Nemaha	NW NE 26	6 N	13 E	2,134	Alluvium on Permian	Hunton	Continental Petr. Corp., Neb.			Dry and abandoned
30	Nemaha	SW NW 36	6 N	14 E	2,560	Pleistocene on Permian	Hunton	Bow & Arrow Oil Co.			Dry and abandoned
31	Nemaha	W_2 NE 10	6 N	15 E	775	Pleistocene on Pennsylvanian	Pennsylvanian	Ellis, Craig & Searle			Abandoned—mech. diff.
32	Otoe	NE NE 3	7 N	9 E	2,126	Pleistocene on Permian	Pre-Cambrian	Parker Oil Co.			Dry and abandoned
33	Otoe	SW SW 1	8 N	10 E	1,839	Pleistocene on Pennsylvanian	Pre-Cambrian	Harvey Risk et al.			Dry and abandoned
34	Otoe	SE SW 31	9 N	14 E	2,500	Pleistocene on Pennsylvanian	Arbuckle	Frank Phelps et al.			Dry and abandoned
35	Pawnee	NW NW 4	1 N	10 E	903	Permian	Pre-Cambrian	Henry Blaser et al.			Dry and abandoned
36	Richardson	E_2 NE SE 9	1 N	14 E	2,291	Permian	Hunton	August Krueger & Son			Drilling, Dawson field

37	Richardson..	SW NW SW 10	1 N	14 E	2,275	Permian	Hunton	Power Oil Co.	106 pump	0	Producer, Dawson field
38	Richardson..	C SE SW 6	1 N	16 E	2,514	Pleistocene on Lower Permian	Hunton	R. L. McIntyre et al.			Dry and abandoned
39	Richardson..	SE SW SE 7	1 N	16 E	2,280	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	68 flow 250 E. pump		Producer[a]
40	Richardson..	SW SW SE 7	1 N	16 E	2,273	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	?		Producer[a]
41	Richardson..	C SE SW 7	1 N	16 E	2,277	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	150 (pump)		Producer[a]
42	Richardson..	C NE SW 7	1 N	16 E	2,290	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	240 (pump 12 hr.)		Producer[a]
43	Richardson..	C NW SE 7	1 N	16 E	2,389	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	37 (Pump 8 hr.)		Producer[a]
44	Richardson..	SW SE SE 7	1 N	16 E	2,288	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	70 (flow) 249 (pump)		Producer[a]
45	Richardson..	C SW NW 8	1 N	16 E	2,446 P. B. 2,379	Pleistocene on Lower Permian	Hunton	H. S. Campbell et al.	30 (pump)		Producer[a]
46	Richardson.	CSW NW 17	1 N	16 E	2,303	Pleistocene on U. Pennsylvanian	Hunton	Ohio Oil Co.			Dry and abandoned
47	Richardson..	NW SE SW 17	1 N	16 E	2,313	Pleistocene on U. Pennsylvanian	Hunton	Ohio Oil Co.	706 (flow)		Producer[a]
48	Richardson..	SW NE SW 17	1 N	16 E	2,299	Pleistocene on U. Pennsylvanian	Hunton	Ohio Oil Co.	557 (flow)		Producer[a]
49	Richardson..	SW NW SW 17	1 N	16 E	2,321	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	73 (pump)		Producer[a]
50	Richardson..	W_2 SE S_2 17	1 N	16 E	2,302	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	420 (pump)		Producer[a]
51	Richardson.	SE NE SW 17	1 N	16 E	2,309	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	60 (pump)		Producer[a]
52	Richardson..	NW NE SW 17	1 N	16 E	2,360	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.			Dry and abandoned
53	Richardson..	C W_2 W_2 17	1 N	16 E	2,307	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.			Dry and abandoned
54	Richardson..	C S_2 S_2 SW 17	1 N	16 E	2,324	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	378 (flow 18 hr.) 717 (pump)		Producer[a]
55	Richardson..	W_2 SE SE 17	1 N	16 E	2,320	Alluvium on U. Pennsylvanian	Hunton	Towle et al.			Fishing
56	Richardson..	SW SW SW 17	1 N	16 E	2,289	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	106 (pump 6 hr.)		Producer[a]
57	Richardson..	C SE NE 18	1 N	16 E	2,320	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.			Dry and abandoned
58	Richardson..	NW NW NE 18	1 N	16 E	2,274	Alluvium on U. Pennsylvanian	Hunton	Winters et al.	368 (pump)		Producer[a]
59	Richardson..	NE NE NW 18	1 N	16 E	2,285	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	236 (pump 21 hr.)		Producer[a]
60	Richardson..	C SW SW 19	1 N	16 E	2,642	Pleistocene on Lower Permian	Hunton	Isaacs & Towle			Dry and abandoned
61	Richardson..	NW NW NE 20	1 N	16 E	2,335	Alluvium on U. Pennsylvanian	Hunton	Skelly Oil Co.	626 (pump)		Producer[a]
62	Richardson..	SW NW NE 20	1 N	16 E	2,320	Alluvium on U. Pennsylvanian	Hunton	Skelly Oil Co.	90 (pump)		Twin well producer[a]
63	Richardson..	E_2 NE SE 20	1 N	16 E	2,325	Alluvium on U. Pennsylvanian	Hunton	R. L. Campbell et al.	176 (pump)		Producer[a]
64	Richardson..	W_2 NE SE 20	1 N	16 E	2,260	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	52 (pump 2 hr.)		Producer[a]
65	Richardson..	NW NE SW 20	1 N	16 E	2,236	Alluvium on U. Pennsylvanian	Hunton	Ohio Oil Co.	22 (pump 4 hr.)		Producer[a]
66	Richardson..	SE SW 20	1 N	16 E	2,282	Alluvium on U. Pennsylvanian	Hunton	R. L. Campbell et al.	576 (pump 7½ hr.)		Producer[a]
67	Richardson..	N_2 NW 20	1 N	16 E	2,312	Alluvium on U. Pennsylvanian	Hunton	Harper Oil Co.	320 (flow)		Producer[a]
68	Richardson..	SE NE NW 20	1 N	16 E	2,310	Alluvium on U. Pennsylvanian	Hunton	Harper Oil Co.	200 (pump)		Producer[a]
69	Richardson..	NE NE NW 20	1 N	16 E	2,896 P. B. 2,461	Alluvium on U. Pennsylvanian	Viola	Harper Oil Co.	876 (flow)		Producer[a] plugged b to Hunton
70	Richardson..	SE NW SW 20	1 N	16 E	2,360	Pleistocene on U. Pennsylvanian	Hunton	J. & M. Oil Co.			Dry and abandoned
71	Richardson..	N_2 S_2 N_2 S_2 20	1 N	16 E	2,326	Alluvium on U. Pennsylvanian	Hunton	Skelly Oil Co.	186 (pump)		Twin well producer[a]
72	Richardson..	N_2 NE NW 29	1 N	16 E	2,428	Pleistocene on U. Pennsylvanian	Hunton	R. L. Campbell et al.	125 (pump)		Producer[a]
73	Richardson..	C SW SW 5	2 N	13 E	1,956	Alluvium on Pennsylvanian	Pre-Cambrian	J. E. Palensky et al.			Dry and abandoned
74	Richardson..	SW SW SW 5	2 N	13 E	1,598	Alluvium on Pennsylvanian	Viola	J. E. Palensky et al.			Dry and abandoned
75	Richardson..	SW SW 15	2 N	13 E	2,604	Alluvium on Pennsylvanian	Hunton	McNulty & Bass			Abandoned—mechanical difficulties
76	Richardson..	NW SW 15	2 N	14 E	2,661	Pleistocene on Lower Permian	Hunton	National Petr. Co.			Dry and abandoned
77	Richardson..	NE NE NE 1	2 N	15 E	2,628	Pleistocene on Lower Permian	Hunton	Midland Oil Co.			Dry and abandoned
78	Richardson..	W_2 NW NE 31	2 N	15 E	2,855	Pleistocene on Lower Permian	Hunton	Rich-Co. Oil Co.			Dry and abandoned
79	Richardson..	NW NW 4	2 N	16 E	2,571	Pleistocene on Lower Permian	Hunton	J. & M. Oil Co.			Dry and abandoned
80	Richardson..	NW SW 8	2 N	16 E	2,550	Pleistocene on Lower Permian	Hunton	Transcontinental Petr. Co.			Dry and abandoned
81	Richardson..	SE SE 25	3 N	15 E	2,705	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	75 (est. on pump)		Abandoned producer
82	Richardson..	NE NE 36	3 N	15 E	2,573	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.			Show oil. Dry and abandoned
83	Richardson..	W_2 SW SW 25	3 N	16 E	670	Pleistocene on Lower Permian	Pennsylvanian	Skelly Oil Co.			Drilling
84	Richardson..	E_2 NE SW 26	3 N	16 E	1,057	Pleistocene on Lower Permian	Pennsylvanian	O. C. Johnson et al.			Drilling

[a] Well in Falls City field.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.	Gas, Millions Cu. Ft.	
85	Richardson..	SW SW 29	3 N	16 E	2,476	Pleistocene on Lower Permian	Hunton	Indian Territory Illuminating Oil Co.	88 (pump)		Producer[b]
86	Richardson..	SE SW 30	3 N	16 E	2,638	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	137 (pump)		Producer[b]
87	Richardson..	SW SW 30	3 N	16 E	2,521	Pleistocene on Lower Permian	Hunton	Henry Bolln Trustee	170 (pump)		Producer[b]
88	Richardson..	NW SW 30	3 N	16 E	2,700	Pleistocene on Lower Permian	Hunton	Henry Bolln Trustee			Dry and abandoned
89	Richardson..	SE SE 30	3 N	16 E	2,503	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	10 (pump)		Show oil, abandoned
90	Richardson..	NE NE 31	3 N	16 E	2,478	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	40 (pump)		Producer[b]
91	Richardson..	SE NE 31	3 N	16 E	2,585	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	30 (pump)		Producer[b]
92	Richardson..	E$_2$ NW NW 31	3 N	16 E	2,539	Pleistocene on Lower Permian	Hunton	W. H. Martgan et al.	166 (pump)		Producer[b]
93	Richardson..	E$_2$ N$_2$ NW 31	3 N	16 E	2,500	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	34 (pump)		Producer[b]
94	Richardson..	NW NW 32	3 N	16 E	2,578	Pleistocene on Lower Permian	Hunton	Black Gold Operating Co.	10 (swab)		Show oil abandoned
95	Richardson..	E$_2$ NE SE 35	3 N	16 E	2,654	Pleistocene on Lower Permian	Hunton	Harry Harper			Dry and abandoned
96	Richardson..	E$_2$ NE NE 35	3 N	16 E	2,505	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	164 (pump 12 hr.)		Producer[c]
97	Richardson..	N$_2$ NW 36	3 N	16 E	2,517	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	680 (pump)		Producer, discovery well[c]
98	Richardson..	S$_2$ NW 36	3 N	16 E	2,486	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	577 (pump)		Producer[c]
99	Richardson..	W$_2$ SW NW 36	3 N	16 E	2,505	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	376 (pump 20 hr.)		Producer[c]
100	Richardson..	W$_2$ NE SW 36	3 N	16 E	2,510	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	122 (pump 14 hr.)		Producer[c]
101	Richardson..	W$_2$ NW NW 36	3 N	16 E	2,495	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	120 (pump 14 hr.)		Producer[c]
102	Richardson..	E$_2$ SE NW 36	3 N	16 E	2,461	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.	367 (pump 22 hr.)		Producer[c]
103	Richardson..	W$_2$ SE SW 36	3 N	16 E	2,508	Pleistocene on Lower Permian	Hunton	Skelly Oil Co.			Waiting on cement
104	Sarpy......	NW NW SW 3	12 N	11 E	665	Pleistocene on Pennsylvanian	Silurian	Allen and Sherritt			Drilling
105	Sarpy......	S$_2$ SW SE 15	13 N	12 E	420	Pleistocene on Pennsylvanian		L. K. Hough et al.			Drilling suspended
106	Scottsbluff..	NW SW 6	20 N	54 W		Tertiary-Brule clay		Fuerst Production Co.			Drilling
107	Valley......	SW NW 28	18 N	13 W	3,535	Pleistocene on Tertiary (Ogallala)	Pre-Cambrian	Henry Bredthauer et al.			Dry and abandoned

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1941	4	10
Number of oil wells completed during 1941	41	1
Number of gas wells completed during 1941	0	0
Number of dry holes completed during 1941		48
Number of wells shut down for orders Dec. 31, 1941		3

[b] Shubert field.
[c] Barada field.

Richardson County, as the result of the drilling of the Skelly Oil Company's No. 1 Roesch. Before the close of the year seven producing wells had been completed in this new field on 20-acre spacing pattern, in the western half of sec. 36 and the northeast quarter of sec. 36, although only six of these wells were on production at the end of the year. This field is on a relatively sharp northwest-trending anticline with an estimated structural closure of 70 ft. or more on top of the Hunton formation. The producing formation is the Hunton dolomite of Devonian age. Although initial tests indicated from 300 to over 600 bbl. of clean oil per day for the wells in this field, the production per well per day is now being limited to approximately 100 bbl. and an orderly development is anticipated. The gravity of the oil in the Barada field is 29.6°.

A second development of considerable importance was the discovery of a lower pay zone in the Hunton formation under the structurally higher parts of the Falls City field, occurring approximately 80 ft. below the top of this formation. As far as known, approximately the same oil-water contact level (−1400 ft.) exists in all of the zones of porosity that are producing in the field. The lower Hunton pay is popularly known as the second Hunton but in reality it is a third zone of porosity. The discovery of the third Hunton porosity zone resulted in the drilling of several "twin" wells.

A third development of some significance was the discovery of a partly oil-saturated section in the Kansas City-Lansing interval of Pennsylvanian age, in two wells drilled in Harlan County, both of which were carried to the Arbuckle without favorable results in the lower formations. One of these wells (sec. 15, T. 2 N., R. 18 W.) has been partly tested without very encouraging results but the other well (sec. 15, T. 1 N., R. 13 W.) has not been tested.

There has been some change in drilling and completion technique in the Richardson County fields during the past year. It has been customary to drill with rotary tools to or into the top of the Hunton formation, then to set a production string and drill the well in with cable tools. It is now the policy of many operators to use rotary entirely; the Hunton formation is cored to or below the water level, the production string is cemented through the producing horizons and the wells are gun-perforated at saturated and porous zones, the placing of perforations being based on core analyses or electric logs or both. Acidization generally follows gun perforation, although the amounts of acid now used (about 500 gal.) is generally smaller than was injected previously.

The drilling of additional wells in the Falls City field during the first half of 1941 resulted in keeping the production for the field at a fairly constant level, although the production per well per day dropped about 30 bbl. The discovery of a lower producing zone in the Hunton materially boosted production to a maximum of about 2000 bbl. per day above that of the early part of the year (4300 bbl. per day) and increased the production in barrels per day per well from 119 during June to 148 in August. Since August the production for the entire field per day has declined about 750 bbl. and the production per well per day has fallen from 148 to 87 barrels.

Production in the Shubert field was erratic throughout the year, varying from an average production of 29 bbl. per day during January, when only one well was in production, to a maximum of 343 bbl. per day during July, when eight wells were producing. The Shubert field was extended during the year to include the southwest quarter of sec. 29, the south quarter of sec. 30, the north quarter of sec. 31, all in T. 3 N., R. 16 E. and the southeast 40 acres of sec. 25, T. 3 N., R. 15 E.

Oil and Gas Development in New Mexico in 1941

By John M. Kelly,* Junior Member A.I.M.E.

New Mexico produced 39,751,868 bbl. of oil in 1941 and ranked seventh among the oil-producing states. Its 1941 production established an annual record, exceeding the 1940 record year by 854,498 bbl. The average daily production for the year was 108,909 bbl. The average daily nonmarginal well allowable for New Mexico on Jan. 1, 1941, was 36 bbl.; at the close of the year it was 43 bbl. The average daily pipe-line runs were approximately 3 per cent less than the allocations of the New Mexico Oil Conservation Commission, which followed closely the recommendation of the United States Bureau of Mines in setting the daily outlet demand. The production in Lea County was 34,333,448 bbl.; Eddy County, 5,009,354 bbl.; and northwestern New Mexico (San Juan and McKinley Counties), 406,306 barrels.

The total number of completions in the state was 402, of which 301 were oil wells, 19 gas wells, and 82 dry holes. Drilling during 1941 was 68 per cent of 1940, and the ratio of dry holes to producers, 1 to 4, was the greatest since 1935. Of these dry holes 43 were drilled in proven fields and 39 were wildcats. One new oil field and one new gas field were discovered as a result of the 1941 wildcatting program. However, numerous extensions were made to the existing fields, which, although they were called extensions to proration areas, were in reality field discoveries, being on separate geologic structures.

SOUTHEASTERN NEW MEXICO

Lea County

The Monument field was the largest producing field in Lea County, with 6,973,808 bbl. It was closely followed by the Eunice field, with 6,644,181 bbl.; Vacuum field, with 4,800,608 bbl. and Hobbs, with 3,624,159 bbl. Hobbs field, however, still has the largest total recovery, this being 97,407,929 bbl. at the end of 1941.

The new oil-field discovery in Lea County during 1941 was the Salt Lake field, T. 20 S., R. 33 E. The discovery well was Leonard-Welch State No. 1, NW. NW. of sec. 18, T. 20 S., R. 33 E. This well was drilled to a total depth of 3103 ft. and was completed for an initial production of 250 bbl. per day pumping. The oil is 26° gravity and the producing horizon is in the San Andres limestone of Permian age. The discovery well was completed on June 22, 1941, and since that date four more producers have been completed, with no failures. The area is about 10 miles northwest of the Lynch pool, to which the oil from this field is being trucked because there is no pipe-line connection.

The greatest drilling activity during 1941 was in the Maljamar field of western Lea County, with 62 completions, 59 being oil wells and 3 dry holes. The limits of this pool are now being defined on the north and south but to date have not been defined either to the east or west. The total number of 40-acre oil-producing units in the field at the close of the year was 158.

On April 1, 1941, a pressure-maintenance project was installed at the southern end

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TABLE 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
1	Arrowhead, *Lea*	1938	4,000	1,880	3,014,155	1,422,150
2	Artesia, *Eddy*	1923	7,160	160	4,607,034	159,079
3	Aztec-Bloomfield, *San Juan*	1924	90	80	40,710	959
4	Barber, *Eddy*	1936	640	40	155,375	85,996
5	Blanco, *San Juan*	1929	40	40	1,396*y*	21
6	Caprock, *Lea*	1940	40	0	1,546	1,546
7	Comanche, *Chaves*	1936	120	0	8,190*y*	2,760
8	Cooper, *Lea*	1929	4,240	160	13,093,773	1,032,739
9	Corbin, *Lea*	1938	80	40	26,624	15,846
10	Dayton, *Eddy*	1940	400	40	38,889	30,219
11	Eaves, *Lea*	1929	880	160	1,607,551	289,593
12	Eunice, *Lea*	1928	20,200	18,240	53,598,235	6,644,181
13	Fulcher Basin, *San Juan*	1934	0	580	0	0
14	Getty, *Eddy*	1928	240	0	604,107	50,930
15	Grayburg Jackson, *Eddy*	1936	7,040	160	10,109,357	1,631,012
16	Halfway, *Lea*	1939	400	0	177,988	112,318
17	Hardy, *Lea*	1935	5,040	200	3,929,792	778,062
18	High Lonesome, *Eddy*	1939	360	160	21,562	12,818
19	Hobbs, *Lea*	1928	10,160	10,040	97,407,929	3,624,159
20	Hogback, *San Juan*	1922	160	0	2,097,982	72,553
21	Hospah, *McKinley*	1927	300	0	384,715	194,133
22	Jal, *Lea*	1927	1,400*y*	520	6,229,920	129,471
23	Kutz Canyon, *San Juan*	1927	0	2,520	0	0
24	Langlie, *Lea*	1927	5,360	600	6,738,162	1,368,092
25	Leo, *Eddy*	1939	240	0	54,509	16,279
26	Leonard, *Eddy*	1929	1,960	400	1,165,362	305,342
27	Loco Hills, *Eddy*	1939	7,160	80	4,936,351	2,304,373
28	Lynch, *Lea*	1929	440	0	6,041,955*y*	153,244
29	Lynn, *Lea*	1929	1,480	160	1,324,544	347,384
30	Maljamar, *Lea*	1926	6,040	0	3,795,759	1,638,031
31	Mattix, *Lea*	1936	7,600	360	6,085,217	1,396,718
32	McMillan, *Eddy*	1938	80	0	389	81
33	Monument, *Lea*	1934	20,000	16,080	45,811,162	6,973,808
34	North Lynch, *Lea*	1929	80	0	1,031,066	8,418
35	North Maljamar, *Lea*	1939	40	0	2,672	890
36	Penrose, *Lea*	1935	7,620	5,120	6,931,340	1,203,831
37	Rattlesnake, *San Juan*	1924	640	0	4,522,574	101,791
38	Red Lakes, *Eddy*	1924	2,640	680	502,688	140,927
39	Red Mountain, *McKinley*	1933	20	0	5,400*y*	750*y*
40	Rhodes, *Lea*	1928	1,220	440	397,501	144,054
41	Robinson, *Eddy*	1926	560	40	390,392	56,307
42	Salt Lake, *Lea*	1941	200	0	14,030	14,030
43	Shugart, *Eddy*	1938	1,320	0	478,872	215,991
44	Skaggs, *Lea*	1936	120	0	75,331	23,283
45	Skelly, *Lea*	1936	3,520	2,440	2,686,493	537,075
46	South Eunice, *Lea*	1930	3,840	200	4,834,171	961,631
47	South Lovington, *Lea*	1938	4,040	200	1,180,941	523,675
48	South Maljamar, *Lea*	1939	240	0	31,216	23,324
49	Table Mesa, *San Juan*	1925	100	0	574,258	36,101
50	Ute Dome, *San Juan*	1921	0	640	0	0
51	Vacuum, *Lea*	1929	14,000	0	13,279,896	4,800,608
52	West Eunice, *Lea*	1928	640	0	317,891	165,287
53	Wills, *Eddy*	1941	0	40	0	0
54	Total		154,190*y*	62,500*y*	310,370,344*y*[1]	39,751,868*y*

[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Included in this total is 3,372 bbl. oil produced from Black River and Grand Plains fields, which have been abandoned.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation^d
	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941	
				Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^e	Flowing	Artificial Lift			
1	4,624	2,143	101	8	0	0	101	0	101	0	1,460	1,363	0
2	16,549	1,549	201*y*	21	2	0	177	3	4	173	*y*	*y*	0
3	*x*	*x*	33	3	*x*	10	10	2	0	10	*x*	0	0
4	0	0	17	6	0	0	16	1	0	16	550*y*	500*y*	0
5	305	44	1	0	0	0	1	1	1	0	1,200	1,000	0
6	0	0	1	0	0	1	0	0	0	1	*x*	*x*	0
7	*x*	*x*	3	0	0	0	3	0	0	3	*x*	*x*	0
8	106,608	7,191	110	2	2	0	87	5	24	53	1,398*x*	*x*	0
9	0	0	3	1	0	1	2	0	2	0	1,398	*x*	0
10	18	14	11	4	0	1	10	0	5	5	*x*	*x*	0
11	8,148	1,530	26	4	0	0	23	2	13	10	*x*	*x*	0
12	216,207	22,890	508	1	0	0	491	2	435	56	1,400	1,014	0
13	635	418	7	4	0	0	0	7	0	0	576	576	0
14	0	0	9	0	0	4	5	0	0	5	0	0	0
15	14,871	6,132	186	41	0	0	176	2	139	37	*x*	*x*	0
16	0	0	10	3	0	0	9	0	0	9	*x*	*x*	0
17	14,835	3,039	126	1	1	0	120	0	95	25	1,400	*x*	0
18	290	180	13	2	0	6	7	4	2	5	*x*	*x*	0
19	204,989	5,153	268	2	0	0	252	4	218	34	1,550	1,183	0
20	*x*	*x*	7	0	0	0	7	0	7	0	200*x*	100	0
21	0	0	20	7	0	0	20	0	0	20	*x*	*x*	0
22	37,280	5,259	48	1	5	0	18	13	6	12	*x*	*x*	0
23	12,958	1,983	17	0	0	0	0	17			265	420	0
24	62,184	20,429	150	1	1	0	126	21	112	14	1,450	*x*	RP
25	20	6	6	0	0	0	6	0	1	5	*x*	*x*	0
26	1,157	547	59	12	1	0	46	8	31	15	*x*	*x*	0
27	7,464	3,473	189	18	0	2	181	0	151	30	950	661	PM
28	0	0	16	0	0	0	11	0	0	11	*x*	*x*	0
29	7,537	2,288	41	1	0	0	29	0	23	6	1,365	*x*	0
30	16,553	1,553	158	59	0	1	142	0	126	16	*x*	*x*	0
31	32,395	11,304	178	10	0	0	156	10	136	20	1,400	*x*	0
32	0	0	2	1	1	0	1	0	0	1	*x*	*x*	0
33	126,031	16,372	508	6	0	0	498	0	483	15	1,427	1,270	0
34	36	4	2	0	0	0	2	0	0	2	*x*	*x*	0
35	3	3	1	0	0	0	1	0	0	1	*x*	*x*	0
36	34,664	8,294	193	6	1	0	191	0	160	31	*x*	*x*	0
37	0	0	78	0	0	2	41	0	0	41	*x*	*x*	0
38	686	435	81	32	4	0	63	16	0	63	*x*	*x*	0
39	0	0	7	0	0	0	6	0	0	6	*x*	*x*	0
40	41,454	11,280	39	7	1	0	15	8	13	2	1,397	*x*	0
41	156	22	15	1	0	0	13	0	1	12	*x*	*x*	0
42	0	0	5	5	0	0	5	0	0	5	*x*	*x*	0
43	194	88	33	6	0	0	29	0	19	10	*x*	*x*	0
44	228	58	3	0	0	0	3	0	1	2	*x*	*x*	0
45	10,738	6,645	97	8	0	0	82	4	58	24	1,420	1,300*y*	0
46	17,602	3,540	99	1	0	0	75	2	71	4	1,455	1,175	0
47	936	475	43	6	0	0	40	1	31	9	1,670	1,191	0
48	3	3	6	4	0	0	5	0	4	1	*x*	*x*	0
49	0	0	6	0	0	0	6	0	0	6	*x*	*x*	0
50	7,379	910	3	0	0	0	0	3			720	560	0
51	10,847	3,443	381	13	0	0	341	0	288	53	1,630	1,269	0
52	2	2	15	6	0	0	15	0	3	12	1,300	1,200	0
53	0	0	1	1	0	1	0	0	0	0	*x*	*x*	0
54	1,016,586*y*	148,699*x*	4,141*y*	315	19	29	3,664	136	2,764	891			

TABLE 1.—(*Continued*)

Line Number	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
1	36	1*y*	San Andres	Per	D	Cav	3,720	3,800	80	A	San Andres Per	3,880
2	35	1.039	San Andres	Per	LS	*x*	445 1,875	480 2,000	*x*	AM	San Andres Per	4,035
3	55	0.1	Farmington sand	CreU	S	*x*	750	1,075	25	S	Lewis Shale CreU	2,665
4	20.5	0.9	Capitan	Per	L	Cav	1,459	1,523	*x*	A	Capitan Per	1,953
5	54	0.13	Mesa Verde and Pictured Cliffs	CreU	S	*x*	4,250	4,550	5	H	Mesa Verde CreU	4,550
6	36	1	San Andres	Per	S	*x*	3,025	3,052	27	A	San Andres Per	3,052 P.B. 4,085
7	28.5	0.9	San Andres	Per	S	*x*	*x*	1,283	*x*	ML	Capitan Per	1,400
8	29.9	1.50	White lime	Per	D	Cav	3,542	3,609	55	A	Lower San Andres Per	5,095
9	30.5	1	White lime	Per	D	Cav	4,258	4,322	45	A	San Andres Per	4,139 P.B. 5,118
10	20.5	0.10	San Andres	Per	LS	Fis	1,096	1,166	50	A	San Andres Per	2,545
11	28.5	1	Permian sand	Per	S	*x*	3,170	3,260	*x*	A	San Andres Per	3,542
12	33.8	1.28	White lime	Per	D	Cav	3,800	3,882	75*y*	A	San Andres Per	4,404
13			Pictured Cliffs	CreU	S	*x*	1,800	1,960	160	H	Pictured Cliffs CreU	1,989
14	24	0.9	Capitan	Per	LS	*x*	1,365	1,380	15	A	Permian	6,683
15	35.5	0.940	Permian sand and White lime	Per	LS	*x*	3,650	3,707	45	A	San Andres Per	4,383
16	28.6	0.9	White lime	Per	LS	*x*	2,590	2,630	25	A	San Andres Per	4,005
17	35	0.9	Permian sand and White lime	Per	D	Cav	3,710	3,763	53	A	San Andres Per	3,872
18	34.9	1.56	Permian sand and White lime	Per	LS	*x*	2,610	2,676	40	A	San Andres Per	3,850
19	34.5	1	White lime	Per	D	Cav	4,050	4,174	123	A	San Andres Per	4,500
20	60	0.1	Dakota sand	CreU	S	*x*	705	714	9	D	McElmo CreL	1,225
21	29	0.15	Hospah sand	CreU	S	*x*	1,639	1,650	11	DF	Dakota CreU	3,282
22	36	1	White lime	Per	D	Cav	3,303	3,334	31	A	San Andres Per	4,125
23			Pictured Cliffs	CreU	S	*x*	1,840	1,900	60	H	Mesa Verde CreU	4,400
24	38	0.9	Permian sand	Per	S	*x*	3,350	3,530	*x*	A	San Andres Per	4,385
25	35.8	0.94	Permian sand	Per	S	*x*	3,170	3,275	*x*	ML	San Andres Per	3,857
26	36	0.900	Permian sand	Per	S	*x*	2,760	2,816	*x*	A	San Andres Per	3,591
27	36.5	0.90	Permian sand	Per	S	*x*	2,615	2,815	*x*	A	San Andres Per	3,453
28	30	1	White lime	Per	D	Cav	3,760	3,777	17	A	San Andres Per	4,046
29	29.5	1	Permian sand and White lime	Per	D	Cav	3,550	3,793	*x*	A	San Andres Per	5,095
30	32	0.9	White lime	Per	L	*x*	3,970	4,060	*x*	A	San Andres Per	4,725
31	37.3	1	Permian sand	Per	S	*x*	3,500	3,554	45	A	San Andres Per	4,200
32	29	1	Carlsbad	Per	S	*x*	1,200	1,414	*x*	A	San Andres Per	3,305
33	34.1	1.20	White lime	Per	D	Cav	3,829	3,938	89	A	San Andres Per	4,534
34	30	1	White lime	Per	D	Cav	3,760	3,777	17	A	San Andres Per	4,046
35	33	1	White lime	Per	D	*x*	3,875	4,015	75	A	San Andres Per	4,097
36	35.2	1	Permian sand	Per	S	*x*	3,550	3,668	90	A	San Andres Per	4,705
37	64.5	0.20	Dakota	CreU	S	*x*	784	808	24	AF	Ignacio Quartzite Cam	7,397
38	36.2	0.9	San Andres Permian	Per	S	*x*	465 1,904	498 1,930	*x*	A	San Andres Per	2,905
39	42	0.1	Mesa Verde	CreU	S	*x*	438	457	13	AF	Mesa Verde CreU	640
40	35	1	Permian sand	Per	S	*x*	3,050	3,283	*x*	A	San Andres Per	4,115
41	34.5	0.9	White lime and Permian sand	Per	S	*x*	3,919	4,009	80	A	San Andres Per	4,359
42	26	0.9	White lime	Per	LS	*x*	3,032	3,080	48	A	San Andres Per	3,825
43	33	0.9	Permian sand	Per	S	*x*	3,450	3,680	*x*	A	San Andres Per	4,890
44	36	1	White lime	Per	L	*x*	3,800	3,860	60	A	San Andres Per	4,757
45	37.4	1	Permian sand	Per	S	*x*	3,525	3,663	*x*	A	San Andres Per	4,052
46	33	1	White lime	Per	D	Cav	3,775	3,845	70	A	San Andres Per	6,202
47	33	1	White lime	Per	L	*x*	4,350	5,094	*x*	A	San Andres Per	5,302
48	33.5	1	White lime	Per	L	*x*	3,818	3,880	62	A	San Andres Per	4,500
49	57	0.0[illegible]	Dakota sand	CreU	S	*x*	1,325	1,337	12	A	Chinle TriU	3,010
50			Dakota sand	CreU	S	*x*	2,285	2,350	60	D	Dakota Sand CreU	2,350
51	35.5	1	White lime	Per	D	Cav	4,316	4,703	*x*	A	San Andres Per	5,329
52	31	1	White lime	Per	L	*x*	3,773	3,824	51	A	San Andres Per	4,695
53			Permian sand	Per	S	*x*	830	930	*x*	*x*	San Andres Per	2,500
54												

of the Langlie field. This project, the first in New Mexico, embraces 13 oil wells on 520 acres, and it was operating satisfactorily at the close of the year.

TABLE 2.—*Summary of Drilling Operations in New Mexico*

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation
		Sec.	Twp.	Rge.		
1	Chaves	17	9 S	25 E	993	Tertiary
2	Chaves	29	11 S	23 E	2,000	Tertiary
3	Chaves	13	11 S	26 E	2,202	Tertiary
4	Chaves	16	11 S	31 E	3,992	Tertiary
5	Chaves	11	12 S	25 E	1,200	Tertiary
6	De Baca	1	1 N	20 E	1,015	Tertiary
7	Dona Ana	35	22 S	5 E	2,785	Tertiary
8	Eddy	13	16 S	30 E	3,850	Tertiary
9	Eddy	34	16 S	30 E	2,982	Tertiary
10	Eddy	31	16 S	31 E	3,118	Tertiary
11	Eddy	14	17 S	24 E	2,386	Tertiary
12	Eddy	18	17 S	25 E	958	Tertiary
13	Eddy	4	17 S	30 E	2,975	Tertiary
14	Eddy	9	19 S	25 E	1,000	Tertiary
15	Eddy	22	19 S	25 E	1,200	Tertiary
16	Eddy	5	19 S	26 E	1,050	Tertiary
17	Eddy	10	19 S	26 E	1,303	Tertiary
18	Eddy	34	19 S	29 E	2,522	Tertiary
19	Eddy	24	19 S	31 E	2,470	Tertiary
20	Eddy	8	20 S	24 E	3,005	Permian
21	Eddy	19	20 S	23 E	745	Permian
22	Eddy	32	20 S	25 E	916	Permian
23	Eddy	33	20 S	25 E	2,380	Permian
24	Eddy	5	20 S	26 E	1,628	Tertiary
25	Eddy	14	20 S	28 E	963 PB 930	Tertiary
26	Eddy	6	20 S	31 E	2,142	Tertiary
27	Eddy	9	21 S	25 E	1,252	Permian
28	Eddy	15	21 S	27 E	584	Tertiary
29	Eddy	13	21 S	28 E	3,030	Tertiary
30	Eddy	28	24 S	28 E	2,893	Tertiary
31	Lea	16	11 S	38 E	5,312	Tertiary
32	Lea	3	14 S	38 E	5,635	Tertiary
33	Lea	18	16 S	33 E	5,060	Tertiary
34	Lea	4	16 S	35 E	5,507	Tertiary
35	Lea	22	17 S	33 E	4,805	Tertiary
36	Lea	4	19 S	33 E	4,634	Tertiary
37	Lea	31	19 S	34 E	3,701	Tertiary
38	Lea	22	19 S	35 E	5,001	Tertiary
39	Lea	18	20 S	33 E	3,103	Tertiary
40	McKinley	11	14 N	10 W	1,720	Cretaceous
41	McKinley	14	14 N	10 W	1,005	Cretaceous
42	Sandoval	1	12 N	3 W	800	Cretaceous

Eddy County

The Loco Hills field continued to be the largest producing field in Eddy County, with 2,304,373 bbl., followed by the Grayburg-Jackson field with 1,631,012 bbl. and the Leonard field with 305,342 bbl. The Grayburg-Jackson field at the end of 1941 had a total recovery of 10,109,357 bbl., the greatest recovery for any field in Eddy County.

The gas-field discovery for New Mexico during 1941 was in the Wills area, Eddy County, drilled by Sudderth et al. in sec. 14, T. 20 S., R. 28 E. The well was completed at a total depth of 963 ft. plugged back to 930 ft. and had an initial potential of 3000 M cu. ft. of gas per day. At the close of the year this well had no pipe-line connection and was the only completion in the field.

Five extensions to proration areas were completed in 1941 in Eddy County. In sec. 13, T. 16 S., R. 30 E., J. W. Jones reworked an abandoned well and was credited with extending the High Lonesome field to the east. The Jones' Etz No. 1 was completed for 50 bbl. a day from 3850 ft. The High Lonesome field was also extended to the south by Sanders Brothers, who completed their Leonard No. 1, sec. 34, T. 16 S., R. 30 E., at 2982 ft. for 77 bbl. of oil per day.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1941

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	San Andres Permian	A. Pierce, et al.						Dry hole
2	San Andres Permian	R. I. Willson						Dry hole
3	San Andres Permian	Mac T. Anderson						Dry hole
4	San Andres Permian	L. E. Elliott						Dry hole
5	San Andres Permian	Roxana Oil Co.						Dry hole
6	San Andres Permian	Compton Oil Co.						Dry hole
7	San Andres Permian	Al Parker et al.						Dry hole
8	San Andres Permian	J. W. Jones	50	No est.	2			Extension High Lonesome area
9	San Andres Permian	Sanders Brothers	77	0.049	2			Extension High Lonesome area
10	San Andres Permian	Nay Hightower	390	No est.	2			Extension Robinson area
11	San Andres Permian	Brewer Drilling Co.						Dry hole. Aban. 1940 at total depth 1282 ft.
12	San Andres Permian	W. D. Flynn						Dry hole
13	San Andres Permian	Sanders Brothers	58	No est.	2			Extension Grayburg Jackson
14	San Andres Permian	Dooley & Haynes						Dry hole
15	San Andres Permian	S. P. Yates						Dry hole
16	San Andres Permian	Jones and Yates						Dry hole
17	San Andres Permian	O. F. Featherstone						Dry hole
18	San Andres Permian	Flynn Welch & Yates						Dry hole
19	San Andres Permian	P. B. English	130	Pumping	2			Extension Shugart area
20	San Andres Permian	Truett & Tallmadge						Dry hole
21	San Andres Permian	Jack Harris						Dry hole
22	San Andres Permian	Whiting & Grant						Dry hole
23	San Andres Permian	Trojan Oil Co.						Dry hole
24	San Andres Permian	Basin Oil Co.						Dry hole
25	San Andres Permian	Sudderth et al.		3				Discovery Wills area
26	Capitan Permian	N. H. Wills						Dry hole
27	San Andres Permian	Black & Ratliff						Dry hole
28	San Andres Permian	A. & M. Petroleum Co.						Dry hole
29	Capitan Permian	Nick Manetas						Dry hole
30	Delaware Permian	Frederich et al.						Dry hole
31	San Andres Permian	Carl B. King						Dry hole
32	San Andres Permian	Helmerich & Payne						Dry hole
33	San Andres Permian	Fullerton Oil Co.	400 ft. oil in hole					Abandoned
34	San Andres Permian	J. W. Brown	Swabbed small amount oil and water					Abandoned
35	San Andres Permian	Richmond Drilling Co.	Show of oil					Abandoned
36	San Andres Permian	Culbertson & Irwin						Dry hole
37	San Andres Permian	Culbertson & Irwin						Dry hole
38	San Andres Permian	Marshall & Uscan						Dry hole
39	San Andres Permian	Leonard & Welch	250[1]	Pumping	2			Discovery Salt Lake area
40	Dakota Cretaceous	Ambrosia Investors Co.						Dry hole
41	Dakota Cretaceous	A. S. Waddell						Dry hole
42	Dakota Cretaceous	Siemens & Boyd						Dry hole

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1941	90	31
Number of oil wells completed during 1941	295	6
Number of gas wells completed during 1941	18	1
Number of dry holes completed during 1941	43	39

[1] Pumping.

Nay Hightower extended the Robinson area to the southwest by completing his Grier No. 1 at 3118 ft. for 390 bbl. of oil per day, in sec. 31, T. 16 S., R. 31 E.

The Grayburg Jackson area had an extension to the northwest when Sanders Brothers completed their Evans No. 1, sec. 4, T. 17 S., R. 30 E. at 2975 ft. for an initial potential of 58 bbl. per day.

P. B. English extended the Shugart area to the south by completing his Jones No. 1 in sec. 24, T. 19 S., R. 31 E. at 2470 ft. for 130 bbl. of oil per day, pumping.

The greatest drilling activity in Eddy County during 1941 was in the Grayburg-Jackson field, with 45 completions, 40 being oil wells, 1 a gas well and 4 dry holes.

During 1941 the New Mexico Oil Conservation Commission granted the operators in the Loco Hills field a permit for pressure maintenance. The entire field joined in an operating agreement to save and return all gas to the producing horizon at a pressure equal to, or greater than the present formation pressure. At the end of the year this project had been operating about three months, returning the gas through 10 input wells and gathering the produced gas from some 160 oil wells.

Northwestern New Mexico

In San Juan County most of the drilling was confined to the Bloomfield and Fulcher Basin fields. In Bloomfield three gas wells and one dry hole were drilled during 1941. At Fulcher Basin, four gas wells were completed. Rattlesnake continued to be the largest oil-producing field in San Juan County, with 1941 production of 101,791 barrels.

In McKinley County the Hospah field had an active drilling campaign during 1941, seven oil wells being completed. Production from this field during 1941 amounted to 194,133 bbl., placing Hospah the first in rank among oil fields in northwestern New Mexico.

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Oil and Gas Developments in New York during 1941

By C. A. Hartnagel*

During 1941, the total production of crude oil in New York state was 5,185,000 bbl. This represents a small increase over the average for the past five years. From 1921, when the annual production of the state amounted to only 988,000 bbl., there was a regular annual increase in production (excepting one or two years) until the 5,000,000-bbl. mark was reached in 1937. After more than 20 years of oil recovery by flooding methods, it was generally believed, until a few months ago, that the rate of production was nearly at its peak and within a few years the fields would experience a gradual decline as the thicker sands became exhausted and the thinner ones could be worked only at increasing costs.

As a result of the present emergency, however, unusual efforts are being made, in spite of higher costs of operation, to increase the output of Pennsylvania grade oil, to which the New York product belongs. Since most of any increased production would be obtained by flooding, and since floods travel slowly, no large increase in production can be expected for some months to come. During the first year, 10 or 15 per cent increase could be obtained, but maximum production, an increase of perhaps 40 per cent, could not be expected until some time during the second or third year. In the Allegany fields, which account for two thirds of the state's oil production, 1246 wells, including water-intake wells, were drilled during the year; 390 more than in the preceding year and 590 more than in 1939.

It is evident that much of the best oil territory has already been developed. As producers move toward edge properties and thinner sands, returns will be smaller, whereas costs remain the same or, under war conditions, become higher. It is estimated that at least 60 million barrels of oil is in sight and will be produced from the thicker sands by present recovery methods. In the thinner sands and edge properties, some 35 million additional barrels can be produced at a profit only if prices become higher. In view of the fact that there is little hope of finding new oil pools in New York, one of the future problems of the oil producer will be to obtain adequate returns for increased production costs.

The year started with a posted price of $2.15 per barrel of crude. There were five successive price increases until the high of the year was reached at $2.98 on Aug. 14. Eight days later the Office of Price Administration directed that the price be reduced to the June level of $2.75 a barrel, which remained in effect to the end of the year. With rising costs of operation, it is feared that many of the smaller properties cannot continue production unless the Federal price cut is revoked.

During the year, Allegany Refiners Inc., a local enterprise founded in 1933, with plant at Bolivar, western Allegany County, increased its refining capacity from 1000 to 1500 bbl. daily. At the same time equipment was added to make the plant a complete lubricating-oil refinery, including facilities for the refining of wax into the finished product. Previous to the enlargement, it was necessary to sell the wax

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* State Geologist of New York, Albany, N. Y.

TABLE 1.—*Oriskany Wells Completed in New York State in* 1941

County and Township	Name of Well	Elevation, Ft.	Depth to Oriskany Sand, Ft.	Drilled by	Initial Daily Production, M Cu. Ft.	Pressure, Lb. per Sq. In.	Remarks
Allegany County:							
1. Alfred	C. L. Lynch	2,208	4,414	Belmont Q. D. Co.			1200 ft. S. W. in 18 hr. at 4415
2. Allen	Eda L. Jermain	1,771	3,062	Hanley & Bird	2,500	1,260	800 M cu. ft. before shot
3. Allen	F. Woodruff No. 2	1,704	3,006	Higgins et al.			150 M cu. ft. after second shot, but S. W. filled 1500 ft. in 24 hr. Show of oil
4. Allen	Mina G. Phipps	1,661	2,969	Belmont Q. D. Co.			Show of gas at 2976 S. W.
5. Allen	Frank L. Lilley	1,650	3,000	H. French et al.			Show gas and oil at 3002, but 1500 ft. S. W.
6. Andover	Maxon Crandall Est.	2,291	4,904	Empire G. & F. Co.	5,800	1,650	First gas, 1250 M cu. ft. at 4906
7. Birdsall	Dan Monaghan	1,525	2,840	Penn-York			Dry and abandoned
8. Independence	Milford Bassett	2,184	4,937	Empire G. & F. Co.			100 ft. S. W. in 1 hr.
9. New Hudson	Harback	1,484	Horizon 3,355	Hill & McKinney			Top Onondaga 3269. No trace of sand
10. Willing	Clarence Johnson	2,192	4,885	Cunningham			100 M cu. ft. gas and 200 ft. S. W. in 1 hr.
11. Willing	William Shear No. 3	2,143	4,815	Cunningham			140 M cu. ft. gas and 6 bbl. S. W. per day
12. Willing	Patrick Ludden No. 2	2,280	4,973	Cunningham			250 M cu. ft. gas and 1300 ft. S. W. in pipe
Steuben County:							
13. Cameron	Steuben Co. No. 1	1,528	3,897	Belmont Q. D. Co.	16,200	1,475	Gas at 3899
14. Cameron	Glenn H. Boyd No. 1	1,573	3,948	N. Y. S. Nat. Gas	8,600	1,300	Gas at 3955
15. Cameron	Baptist Church Lot	1,504	3,878	C. D. Wharton	5,750	1,000	200 M cu. ft. at 3884, but at 3887 increased to 5750 M cu. ft.
16. Cameron	Herbert Thompson No. 2	1,702	4,080	N. Y. S. Nat. Gas	3,500	760	Gas at 4088. Open flow 475 M, but increased after shot with 5 qt. to 3500 M
17. Cameron	Glenn Boyd No. 2	1,485	3,857	N. Y. S. Nat. Gas	1,700		Gas at 3861 ft.
18. Fremont	Oscar Tuttle	1,581	Horizon 3,214	N. Y. S. Nat. Gas			Top Onondaga 3185; no trace of sand
19. Howard	John Schaumberg No. 1	1,836	3,570	Leiderbach et al.	2,500	1,400	500 M cu. ft. gas increased after shot
20. Howard	Laura Roosa 1-A	1,853	3,589	Hanley & Bird	900	1,470	250 M cu. ft. gas increased after shot
21. Howard	Laura Roosa 1-B	1,852	3,601	Leiderbach et al.	1,500		400 M cu. ft. gas at 3606 increased after shot
22. Howard	L. C. Roosa No. 2	1,723	3,468	Leiderbach et al.	600		First gas at 3471
23. Howard	John Schaumberg No. 2	1,707	3,443	Belmont Q. D. Co.	521		First gas at 3447 ft. At 3452 ft. flow reached 213 M cu. ft. Shot with 20 qt. increased to 521 M
24. Howard	Thomas Moss No. 2	1,678	3,401	Empire G. & F. Co.	1,000		180 M cu. ft. at 3405-7. Shot with 20 qts. increased to 1 MM
25. Jasper	Floyd Sherman	2,236	4,827	Van Gilder et al.			100 M cu. ft. gas at 4833 ft., but S. W. filled hole in 24 hr.
26. Jasper	L. Walrath	1,802	4,189	Kerr & Kaufman			Show of gas at 4189 ft., but S. W. at 4195
27. Rathbone	John McCaig	1,029	3,376	Belmont Q. D. Co.			No gas; 1 bailer S. W. per hour
28. West Union	James Hamilton No. 1	2,128	4,936	Belmont Q. D. Co.			600 M cu. ft. gas at 4938 but 3000 ft. S. W. in 12 hr.
29. West Union	George Lewis No. 1	2,230	5,009	Belmont Q. D. Co.	14,300		Gas at 6 ft. in sand
30. West Union	John Hardin	2,315	5,144	Penn-York			200 ft. S. W. at 5146
31. West Union	James Hamilton No. 1	2,222	5,004	Penn-York	9,000	1,395	First gas at 5007
32. West Union	George Lewis No. 2	2,318	5,098	Belmont Q. D. Co.	16,000	875	First gas, 452 M cu. ft., ½ ft. in sand
33. Woodhull	Burnett Hibbard	1,452	4,253	G. L. Cabot			S. W. at 4255
Chemung County:							
34. Elmira City	Ben Barcus No. 2	843	2,711	Updegraff			50 M cu. ft. gas in Tully. T. D. 3011
35. Elmira City	Hyna Josephson	852	2,715	Rogers et al.	100		
36. Elmira City	C. E. Updegraff No. 2	854	2,712	Updegraff			40 M cu. ft. gas in shallow sands. Dry and abandoned
37. Elmira City	Mary Mangan	857	2,714	Updegraff	560		First gas at 2717
38. Elmira City	Harold Shay	855	2,730	Rogers et al.			Hole filled with S. W. Plugged at 2706
39. Southport	Bert Harder	956	3,095	Rogers et al.			S. W.; show of gas at 3100
Tompkins County:							
40. Dryden	George Hildreth	1,213	1,905	Belmont Q. D. Co.			S. W. at 1908
Wyoming County:							
41. Perry	Frank Eaton	1,330	1,425	G. L. Cabot			Red Medina 2522–86; White Medina 2586–91. Black water 2201
42. Perry	Karl Davis	1,185	1,239	G. L. Cabot			Red Medina 2226–2313. 97 M cu. ft. at 2291 ft.

Total daily initial Oriskany production, 91,031 M cu. ft.

distillates to other plants for further refining. The Bolivar refinery is midway between the two larger refineries of the New York oil fields—the Sinclair at Wellsville and the Socony-Vacuum at Olean.

NATURAL GAS

In 1941, New York state drilling operations for natural gas in the Oriskany sandstone showed a decrease in initial production for the fourth successive year. From an all-time high daily initial production of 403,418 M cu. ft. in 1937, the initial production fell until it was 100,910 M cu. ft. in 1940 and 91,031 M cu. ft. in 1941.

Of the 42 wells drilled during 1941 in the Oriskany sandstone area, 18 were producers. The more important activities were in Steuben and Allegany Counties, not far from the Pennsylvania border. In these two counties, 33 of the total 42 Oriskany wells were drilled, of which 16 were listed as producers. No new production was obtained in the old established fields—State Line, Beech Hill, Greenwood or Woodhull.

Two wells were put down in the Independence-Andover extension of the Beech Hill field in Allegany County, an area that proved promising a year ago. Of these, a well on the Maxon Crandall Estate along the Independence township border in Andover township had an initial production of 5800 M cu. ft. of gas. The second well was dry. The only other new production in Allegany County was from the Eda L. Jermain, in Allen township, which came in with an initial production of 2500 M cu. ft. Of 22 wells drilled in this locality in the last 10 years, six have been producers but only three have passed the million mark.

The total initial production in Allegany County from the two wells named was 8300 M cu. ft. of gas, by way of contrast to the 84,625 M cu. ft. from 13 wells produced in that county one year ago. Initial production likewise reversed itself in Steuben County, where the 1940 production totaled 13,580 M cu. ft. from three wells, and for 1941 totaled 82,070 M cu. ft. of gas from 14 wells.

One-half the 42 Oriskany wells drilled in 1941 were Steuben County wells. Of the 21 wells drilled, two thirds were producers, accounting for 90 per cent of the total initial daily production in New York state for the year. Eight producers in two townships alone, West Union and Cameron, accounted for 82.5 per cent of the total initial production.

In Cameron township, where five producers were drilled in during 1941, new production totaled 35,750 M cu. ft. of gas. One of these, the best producer of the year, Steuben County No. 1, came in at 16,200 M cu. ft. In 1939, nine wells were drilled in this township, all within 2 miles of the 1941 producers, only one of which found gas. Three of five wells drilled in West Union township during 1941 were producers, with initial production totaling 39,300 M cu. ft. of gas. These wells are all in an area of about one mile in diameter. In Howard township, six wells drilled during 1941 all had small production. The wells are close together, and it is doubtful whether the field will be long lived or bring in large wells.

Additional exploratory wells to the Oriskany sandstone were drilled in Tompkins, Chemung and Wyoming Counties, but of these the only successful wells were in Chemung County; there two small producers were completed, contributing less than one per cent to New York state's total initial Oriskany production. As a whole, the known Oriskany sandstone areas are becoming rapidly depleted, numerous tests during the last few years having failed to find any important new Oriskany pools. It is evident that, with the failure to find important new supplies, the use of natural gas in the state must be greatly curtailed unless additional gas can be obtained from other states.

Oil and Gas Development in Ohio in 1941

By Kenneth Cottingham,* Member A.I.M.E.

The year 1941 brought a considerable increase in drilling activity in Ohio. In 1940, the total of wells completed was 1228, whereas in 1941 it was 1561, or an increase of approximately 27 per cent. Of the 1561 wells, 333 were oil wells, 701 gas wells and 527 dry holes. The completions for the past five years are shown in Table 1; the number of productive oil or gas wells for the year 1941, arranged by producing formations, are given in Table 2; the number of wells, oil, gas or dry, completed in each county in 1941, in Table 3, and wells by sands in Table 4.

Table 1.—*Completions in Ohio during Past Five Years*[a]

Year	Number of Wells Drilled during Year			
	Oil	Gas	Dry	Total
1937	317	503	451	1,271
1938	189	433	288	910
1939	170	501	349	1,020
1940	327	491	410	1,228
1941	333	701	527	1,561
Total	1,336	2,629	2,025	5,990

[a] Old wells drilled deeper and water-flood injection wells are not included in this table.

The production of oil increased by about 500,000 bbl. in 1941, nearly all of the increase being in Pennsylvania grade. In 1940, the total production was 3,052,000 bbl. from 25,500 wells. In 1941 the total production was 3,547,534 bbl. from 24,801 wells. The increase in production is chiefly due to the Clinton pool in Clayton township, Perry County, which is briefly mentioned later in this review. The number of oil wells, by grades of oil, and the total quantities produced are shown in Table 5. Annual oil production for five years is listed in Table 6.

The average prices paid for crude in 1941 were slightly higher than in 1940. These 1941 prices, with dates of change, are shown in Table 7.

Table 2.—*Number of Producing Wells Drilled during* 1941, *and Average Initial Production per Well*

Sand	Oil Wells		Gas Wells	
	Number of Wells	Average Initial Daily per Well, Bbl.	Number of Wells	Average Initial Daily per Well, M Cu. Ft.
Shallow	65	4	162	381
Berea	178	6	150	188
Ohio shale	0		26	191
Oriskany	0		7	432
Newburg	1	36	29	1,356
Clinton	80	111	325	1,092
Trenton	9	5	2	50
Sub-Trenton	0		0	
Total	333	31	701	702

The maximum production of natural gas in Ohio was in the year 1915, when the total was just under 80 billion cu. ft. The maximum consumption occurred in the year 1916, and was approximately 169 billion cu. ft. For the past several years, Ohio has ranged from eighth to eleventh, in order of gas production for the different states, being in tenth place in 1940. In the matter of consumption, however, Ohio remains in fifth place.

Preliminary figures for 1940 indicate that production of natural gas increased 11 per

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* Geologist, The Ohio Fuel Gas Co., Columbus, Ohio.

TABLE 3.—*Completions in Ohio in 1941, by Counties*[a]

County	Oil Wells	Gas Wells	Dry Holes	Total
Allen	2		2	4
Ashland	10	20	36	66
Ashtabula		1	2	3
Athens	12	60	43	115
Auglaize			1	1
Belmont		2	7	9
Carroll			3	3
Columbiana	2	4	15	21
Coshocton	8	10	8	26
Cuyahoga		21	7	28
Fairfield		11	3	14
Gallia		9	1	10
Geauga			1	1
Guernsey		10	16	26
Hancock	1			1
Hardin	1		1	2
Harrison		2	8	10
Henry			2	2
Hocking	2	6	6	14
Holmes	1	12	7	20
Jackson			1	1
Jefferson	6	2	8	16
Knox	4	43	30	77
Lawrence		20	2	22
Licking	26	102	46	174
Lorain	1	10	19	30
Lucas			2	2
Mahoning	1	2	3	6
Medina[b]	129	23	47	199
Meigs	2	63	28	93
Mercer	1			1
Monroe	7	31	11	49
Morgan	2	29	19	50
Muskingum	5	45	17	67
Noble	18	34	30	82
Ottawa		1		1
Perry	58	10	11	79
Portage			2	2
Putnam	2			2
Richland		1	1	2
Seneca		1	6	7
Stark		20	5	25
Summit		8	3	11
Tuscarawas		21	10	31
Van Wert			2	2
Vinton		1	3	4
Washington	30	46	32	108
Wayne		20	13	33
Williams			1	1
Wood	2		1	3
Wyandot			5	5
Total	333	701	527	1,561

[a] Old wells drilled deeper during year are not included in this table.

[b] Approximately 105 Berea holes, drilled as water-injection wells, are not included.

cent over 1939 and consumption increased 13 per cent in the same period. Table 8 gives the production and consumption of natural gas in Ohio for the past five years.

DEVELOPMENT DURING 1941

Sub-Trenton.—Interest in the sub-Trenton "Green Sand" horizon has flagged considerably since 1939. In 1941, a total of seven sub-Trenton tests were completed, two of which were in Allen County and one in Wyandot County. The well in Wyandot County found the Trenton at 1305 ft. and reached a total depth of 1910 ft. These three wells were dry.

TABLE 4.—*Wells Completed in Ohio in 1941, by Sands*

Sand	Oil Wells	Gas Wells	Dry Holes	Total
Shallow	65	162	123	350
Berea	178	150	150	478
Ohio shale	0	26	15	41
Oriskany	0	7	4	11
Newburg	1	29	2	32
Clinton	80	325	206	611
Trenton	9	2	20	31
Sub-Trenton	0	0	7	7
Total	333	701	527	1,561

TABLE 5.—*Tabulation by Grade*

Grade	Number of Wells	Barrels
Pennsylvania	11,960	1,508,828
Lima	7,872	549,443
Corning	3,637	1,034,077
Cleveland[a]	1,332	455,186
Total	24,801	3,547,534

[a] Lodi grade combined with Cleveland Sept. 1, 1941.

TABLE 6.—*Annual Oil Production during Past Five Years*

Year	Production, Bbl.	Number of Oil Wells	Average per Well, Bbl.
1937	3,559,000	28,122	127
1938	3,298,000	26,880	123
1939	3,156,000	25,680	123
1940	3,169,000	25,500	124
1941	3,548,000[a]	24,801[a]	143[a]

[a] Preliminary estimates.

A sub-Trenton test was drilled in sec. 8, Howard township, Knox County. The Trenton was reached at 3850 ft., and the total depth was 4945 ft. The well was drilled with only 360 ft. of casing, and as a result identification of formations was difficult because of cavings. There were no shows, and the test was abandoned.

Another similar deep test was in sec. 21, Jersey township, Licking County. The top of the Trenton was at 3320 ft. and a sandy formation that was called St. Peter was found at 3962 to 3979 ft. A very slight show of gas was found at 3975 ft. Water filled the hole at 4350 ft. but drilling continued to 4360 ft. The well was abandoned at this depth.

TABLE 7.—*Prices of Crude Oil in Ohio during* 1941

PER BARREL

Date of Change of Prices	Grade				
	Pennsylvania	Corning	Lima	Cleveland	Lodi
12-31-40	$1.70	$1.12	$1.00	$1.00	$1.00
1-27-41	1.85				
4- 1-41		1.17			
4-23-41	1.95			1.10	1.10
5- 1-41			1.10	1.15	1.15
5- 2-41		1.24			
5-21-41	2.10				
5-27-41		1.31			
5-28-41			1.17	1.22	1.22
6-18-41	2.30				
8-14-41	2.55				
8-23-41	2.30				
9- 1-41				[a]	1.30

[a] Cleveland combined with Lodi grade Sept. 1, 1941.

TABLE 8.—*Natural Gas in Ohio during Five-year Period*

THOUSANDS CUBIC FEET

Year	Annual Production	Annual Consumption
1936	46,994,000	121,381,000
1937	42,783,000	125,133,000
1938	35,257,000	108,013,000
1939	36,469,000	114,720,000
1940	40,639,000	129,856,000

A deeper sub-Trenton test was drilled in sec. 14, Wooster township, Wayne County. The Trenton was from 5014 to 5710 ft. There were shows of oil at 5763 and 5799 ft. This well was both acidized and shot, but finally was abandoned at a depth of 6116 feet.

In Lot 1, Chardon township, Geauga County, a dry hole was drilled to a total depth of 6101 ft. The Trenton was from 5260 to 5987 ft., and a formation identified as St. Peter from 5987 to 6012. The hole filled to within 1100 ft. of the top with water from the St. Peter. The hole was plugged and abandoned at a depth of 6101 feet.

Trenton.—The Trenton drilling was confined to northwestern Ohio. The wells were all very small. Gas wells were drilled in Ottawa and Seneca Counties. Oil wells were completed in Allen, Hancock, Hardin, Mercer, Putnam and Wood Counties.

Clinton.—Wells drilled to the Clinton sand exceeded by a considerable number wells drilled to any other formation. Clinton wells in 1941 exceeded also the number drilled in 1940 by about 43 per cent. The most active county was Licking, in which 4 oil wells, 91 gas wells, and 39 dry holes were drilled to the Clinton sand. Most of these were in the area northeast of the city of Newark, a pool in which the discovery well was drilled in 1938. Perry County had a total of 73 Clinton wells, of which 57 were oil, 7 were gas and 9 were dry. The activity in this county was mainly in Clayton township, in an oil pool discovered in 1936. At least five unusually large oil wells were completed in sec. 8, Clayton township. The initial 24-hr. production of these wells was 575; 407; 372; 340 and 333 bbl. In Knox County, 70 wells were drilled, of which 4 were oil, 39 were gas and 27 were dry. The greatest activity was in Union township. Muskingum County was active also, 67 wells being completed there, of which 5 were oil, 45 were gas and 17 were dry. Drilling in Muskingum County was scattered through several townships, important among them being Brush Creek, Harrison and Salt Creek.

Large Wells

The largest gas well completed in 1941 was the Ohio Fuel Winters No. 1, sec. 5, Salt Creek township, Muskingum County. This well produces from the Clinton sand at a depth of 4123 ft.; it had an initial open flow of 12,000,000 cu. ft. and an initial rock pressure of 1120 lb. In sec.

15, Brush Creek township, Muskingum County, another large well was discovered in the Clinton sand at a depth of 4149 ft., the initial open flow being 11,000,000 cu. ft., with a rock pressure of 755 lb. In sec. 23, York township, Morgan County, in the Clinton at 4254 ft., a well was drilled having 10,998,000 cu. ft. with an initial pressure of 1120 lb. In sec. 22 of the same township, the Clinton yielded 10,000,000 cu. ft. with a rock pressure of 1125 lb. In sec. 11, Harrison township, Muskingum County, at a depth of 4262 ft. in the Clinton, a well was completed having an initial volume of 10,000,000 cu. ft. and a pressure of 740 pounds.

In Lot 53, Hinckley township, Medina County, a Clinton well had an open flow of 6,520,000 cu. ft. and a pressure of 970 lb., from a depth of 3377 ft. In Independence township, Cuyahoga County, the Newburg sand yielded 6,000,000 cu. ft. at a depth of 2720 ft. A large Clinton well was completed in sec. 28, Plain township, Wayne County, having an initial volume of 8,750,000 cu. ft. and an original pressure of 620 lb., the depth of the well being 3169 feet.

The largest of the outstanding oil wells completed in 1941 was the Preston Oil Company's Shaw No. 2, sec. 8, Clayton township, Perry County. This well produced from the Clinton sand, at a total depth of 3269 ft., an initial daily production of 575 bbl. As stated previously, four other large Clinton oil wells were completed in the same section of this township. Other large Clinton wells were two in sec. 14, Pike township, Coshocton County, with initials of 107 and 100 bbl. per day; in Lot 22, Hopewell township, Licking County, initial production 80 bbl. per day; in sec. 7, Jackson township, Knox County, initial 60 bbl. per day; and in sec. 14, Wayne township, Muskingum County, initial 60 bbl. per day.

Deep Wells

The second deepest well in Ohio was a dry hole drilled to the Clinton sand in sec. 19, Smith township, Belmont County, which went to a depth of 7887 ft. and was completed early in 1941. The deep wells in Wooster township, Wayne County (depth 6116), Chardon township, Geauga County (6101), and Howard township, Knox County (4945) have been described under sub-Trenton development. In Monroe township, Carroll County, a Clinton test was dry at a total depth of 5496 ft. In Smith township, Mahoning County, a dry hole was completed in the Clinton at a total depth of 5020 ft. Other deep tests, all dry, were in Elk township, Noble County (Oriskany), total depth 4728 ft.; in Warren township, Washington County (Oriskany), total depth 4651 ft.; and in Marion township, Morgan County (Clinton), total depth 4530 ft.

In Washington township, Harrison County, several Clinton wells were drilled. One of these, in sec. 33, Washington township, had an open flow of 471,000 cu. ft. and an initial rock pressure of 1380 lb., the total depth being 5899 ft. Another, in sec. 32, Washington township, had an initial open flow of 365,000 cu. ft., a rock pressure of 1220 lb., and a total depth of 5820 ft. The other tests were dry, the deepest reaching 6255 ft., in sec. 2, Washington township.

Among the deep producing wells was one drilled in sec. 26, Union township, Tuscarawas County. The total depth of this well was 5289 ft., the producing formation was the Clinton sand, and the initial volume was 559,000 cu. ft., with a rock pressure of 1170 pounds.

OTHER DEVELOPMENT

Interest continued in the water drive in the Berea sand in Chatham township, Medina County. The Berea lies at a depth of approximately 475 ft. here. During the year, 129 Berea oil wells were drilled in the county, most of them in the flood area. In addition to these, approximately 105 water-injection wells were drilled.

An undertaking of considerable engineering and geological importance is the sinking of two shafts by the Columbia Chemical Division of the Pittsburgh Plate Glass Co. at Barberton. Each shaft is approximately 16 by 7 ft. in cross section. On Jan. 1, 1942, one shaft had reached a depth of 1875 ft. and the other was at 1113 ft. The final depths are expected to be 2250 and 2300 ft. The objective is the Delaware limestone (Devonian), which will be mined.

ACKNOWLEDGMENTS

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Oil and Gas Development in Oklahoma in 1941

By Raymond D. Sloan,* Member A.I.M.E.

Development and exploration in Oklahoma showed a definite increase in 1941 over 1940 in production, wildcat activity and total well completions. Geological and geophysical work continued and possibly increased slightly in amount. Oklahoma retained third place in the ranking of oil-producing states of the nation, topped only by Texas and California, and followed by Illinois in fourth position. Production averaged 416,800 bbl. daily, a 1.7 per cent increase, as compared with 409,900 bbl. daily for the year 1940. Maintenance of the state's relatively stable producing rate resulted from the discovery of numerous small pools, the recombing of old areas, the establishment of new producing horizons, and the drilling of an increased number of marginal wells.

The market for the Mid-Continent crude was strengthened materially to meet the increased demand. Coincident with a decline in production in Illinois, shipment of Oklahoma-Kansas crude to the eastern points averaged 453,000 bbl. per day, an increase of 49.4 per cent as compared with 1940. The movement south amounted to an average of 42,000 bbl. per day, a loss of 41.7 per cent.

Secondary-recovery programs in Oklahoma were given more consideration, operators realizing that in the future many pools would necessarily have to resort to this type of operation. Five permits for water-flooding were issued by the Corporation Commission during the year. These projects were in Rogers, Wagoner and Nowata Counties, in the shallow northeastern area, which has relatively extensive development of this type in the Bartlesville sand at from 600 to 1000 ft. in depth. Gas repressuring of an individual lease in the 35-year old Glenn pool, Creek County, proved relatively successful, and after a year's operation was extended to cover a much larger area, with several operators participating. More of this type of work is expected in the future; however, it was given an initial setback when the legislative proposal authorizing secondary recovery in the Wilcox zone of Oklahoma's largest pool, the Oklahoma City pool, was pigeonholed by the committee. A continuation of the low discovery rates within the state would possibly lead to a revival of interest in the project.

Many pools formerly classified as prorated areas were removed from this classification and transferred into the group of settled production.

At the close of the year the issuance of the Federal Conservation Order M-68 and the interrelated Preference Rating Order P-98 caused a sharp decline in drilling operations, which is expected to continue until such operations are stabilized at a lower rate. The ultimate effect of these two orders on discoveries, production and reserves is a matter of speculation and conjecture.

During the year, 2110 new wells were drilled, an increase of approximately 18 per cent as compared with the previous year. Of the total, 1235 were oil wells with a combined initial potential of 342,754 bbl. daily, 178 were gas wells with a total

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TABLE 1.—*Oil and Gas Production in Oklahoma*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	CENTRAL OKLAHOMA												
1	Avery, *Lincoln*	1939	40	7,566	4,380	4				4			4
2	Chandler, *Lincoln*	1924	1,255	11,918,533	260,610					45			45
3	Davenport, *Lincoln*	1924	2,335	11,968,308	161,330	222				117			117
4	North, *Lincoln*	1941	30	15,527	15,527	6	6			6			6
5	West, *Lincoln*	1940	50	58,613	53,290	5	1			5			5
6	Gessman, *Lincoln*	1934	160	386,450	23,360					10			10
7	Hoyt, *Lincoln*	1935	265	1,313,646	62,050	14				9			9
8	Kendrick, *Lincoln*	1940	40	36,079	11,680	1				1			1
9	Laffoon, *Lincoln*	1932	470	1,875,361	199,655	27	8			12			12
10	Lincreek, *Lincoln*	1932	275	229,782	13,870					8			8
11	Payson, *Lincoln*	1940	20	7,597	5,475	1				1			1
12	Peck, *Lincoln*	1926	160	454,526	59,495					5			5
13	Perkins, *Lincoln*	1940	60	162,167	56,575		1			4			4
14	Sac and Fox, *Lincoln*	1924–37	1,830	3,075,651	397,485		1			141			141
15	Skellyville, *Lincoln*	1925	630	1,770,486	29,565					13			13
16	Sporn, *Lincoln*	1936	200	662,546	80,300	10				6			6
17	Stroud, *Lincoln*	1923	590	8,908,922	147,460	69				25			25
18	Wellston, North, *Lincoln*	1936	480	1,368,036	68,620					20			20
19	Wilzetta, *Lincoln*	1934	220	1,061,548	109,865	15	1			12			12
20	South, *Lincoln*	1936	80	155,250	14,600					4			4
21	Miscellaneous, *Lincoln*		170	889,532	19,518					5			5
22	Cleveland, *Pawnee*	1904	4,255	40,152,210	161,695					242			242
23	Greenup, *Pawnee*	1926		*y*	0				Abandoned				
24	Hallet, *Pawnee*	1922	1,665	*y*	25,550					45			45
25	Jennings, *Pawnee*	1916	1,375	3,972,962	80,665					77			77
26	Keystone, *Pawnee*	1919	5,565	2,502,269	144,540					224			224
27	Lauderdale, *Pawnee*	1915	4,300	13,389,515	257,325					192			192
28	Maramec, *Pawnee*	1920	1,990	2,962,717	176,295					92			92
29	Masham, *Pawnee*	1924	290	*y*	7,665					5			5
30	Pawnee, East, *Pawnee*	1941	40	8,731	8,731	2	2			1			1
31	Ralston, *Pawnee*	1924	205	*y*	2,555					2			2
32	Skedee, *Pawnee*	1926	160	200,556	7,665					4			4
33	Terlton, *Pawnee*	1912	980	890,926	19,710					14			14
34	North, *Pawnee*	1917	2,010	3,166,402	73,730					75			75
35	Watchorn, *Pawnee*	1922	530	7,488,767	101,105					17			17
36	Miscellaneous, *Pawnee*		280	*y*	13,140					7			7
37	Broyles, *Payne*	1918–39	170	*x*	31,390					6			6
38	East, *Payne*	1940	60	34,422	4,061		Abandoned during 1941						
39	Coyle, *Payne*	1938–40	988	2,520,187	1,458,905	35	2			35			35
40	Garr, *Payne*	1920	1,135	2,476,335	140,525					33			33
41	Ingalls, *Payne*	1914	1,110	6,106,454	123,735					34			34
42	March, *Payne*	1922	1,410	*y*	31,025					18			18
43	North, *Payne*	1926	155	*y*	25,550					7			7
44	Mehan, *Payne*	Prior to 1925	670	2,334,625	3,650					3			3
45	Northeast, *Payne*	1941	10	10,381	10,381	2	2			2			2
46	New Cushing, *Payne*	1916	185	*x*	0					2			2
47	Norfolk, *Payne*	1916	785	*y*	49,275					14			14
48	West, *Payne*	1929	390	*y*	85,775					23			23
49	Orlando, *Payne*	1929	210	973,313	32,120		1			1			1
50	East, *Payne*	1941	40	55,934	55,934	2	2			2			2
51	Ramsey, *Payne*	1938–40	570	4,923,845	1,528,985	42	4			42		*y*	*y*
52	Ripley, *Payne*	1923	375	*y*	17,520					5			5
53	North, *Payne*	1923	165	2,212,899	25,550					2			2
54	Stillwater, *Payne*	1935	130	518,746	10,950	6				3			3
55	West, *Payne*	1940	40	117,931	64,605	2				2			2
56	Yale-Quay, *Payne*	1914	4,095	22,108,072	552,245					165			165
57	Miscellaneous, *Payne*		160	*y*	7,669					4			4
58	Aggregate for district of pools marked *x* or *y*			5,315,272									
59	Total Central Oklahoma		45,858	170,769,597	7,134,931					1,853			

[c] Footnotes to column heads and explanation of symbols are given on page 250.

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1		44	Prue	Pen								
2		38	Various	Pen, Ord	S, L	Por	3,250	5,020		A		
3		43	Various	Pen	S	Por	2,600	3,580	50	ML		
4		41	Prue	Pen			3,535	3,548	13			
5		46	Prue	Pen								
6		44	Cleveland	Pen	S	Por	y	y		M		
7		40	1st Wilcox	Ord	S	Por	y	5,100	y			
8		50	Prue	Pen								
9		21	Wilcox	Ord	S	Por	4,190	4,275		A	Wilcox	
10		46	Wilcox	Ord	S	Por	y	y				
11		35	Lower Skinner	Pen								
12		23	2nd Wilcox	Ord								
13		43	Hunton	Sil								
14		46	Prue	Pen	S							
15		41	Various	Pen, Sil, Ord Cam	S, L							
16		46	Simpson	Ord	S		4,500	4,600	y			
17		41	Various	Pen, Ord	S	y	4,240	4,290	50		Wilcox	4,520
18		40	Wilcox	Ord	S							
19		40	Hunton, Viola	Sil-Dev, Ord								
20		35	Hunton, Viola	Sil-Dev, Ord								
21		40	Prue, Wilcox	Pen, Ord	S							
22		36	Various	Pen, Ord, Cam	S, L	Por	1,300	2,400				
23												
24		38	Various	Pen, Ord								
25		37	Various	Pen, Mis, Ord	S, L	y	y	y				
26		37	Various	Pen, Mis, Ord	S, L		1,100	1,970				
27		37	Various	Pen, Ord, Cam	S, L		1,185	3,000				
28		37	Various	Pen			2,400	3,200				
29		39	Various	Pen, Mis, Ord	S, L							
30		42	Misener	Mis			3,363	3,367	4			
31		39	Various	Pen, Ord								
32		40	Bartlesville, Burgess, Skinner	Pen	S							
33		38	Various	Pen, Ord								
34		38	Various	Pen, Ord				y	y			
35		41	Various	Pen, Mis, Ord	S, L	Por						
36		37	Bartlesville, Wilcox	Pen, Ord	S							
37		43	Bartlesville, Viola, Wilcox	Pen, Ord	S, L							
38		36										
39		46	Hunton, Wilcox	Sil, Ord	S, L	y	y	y	y			
40		38	Various	Pen, Mis, Ord	S, L							
41		39	Various	Pen, Mis, Ord	S, L		3,115	3,760				
42		38	Various	Pen, Ord								
43		43	Wilcox	Ord	S							
44		43	Various	Pen, Mis, Sil-Dev, Ord								
45		38	1st and 2nd Wilcox	Ord			4,065 4,100	4,076 4,103	11 3			
46		38	Various	Pen, Ord								
47		38	Bartlesville, Wilcox	Pen, Ord	S							
48		38	Bartlesville, Wilcox	Pen, Ord	S							
49		41	Misener	Mis	S							
50		42	Misener	Mis	S		4,720	4,747	27			
51		43	1st Wilcox	Ord	S		4,768	4,795	27			
52		43	Various	Pen, Ord	S, L							
53		43	Wilcox	Ord	S	Por	y	y	y	y		
54		40	Wilcox	Ord	S	Por	4,300	4,306	6	A		
55		40	Hunton	Sil								
56		38	Oswego, Bartlesville, Wilcox	Pen, Ord	S, L		2,670	3,580				
57		39	1st and 2nd Wilcox	Ord								
58												
59												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[e]	Producing Gas[e]	Flowing	Artificial Lift
	EAST CENTRAL OKLAHOMA												
60	Hoffman, *McIntosh*	1917	300	*x*	2,190					4			4
61	Miscellaneous, *McIntosh*		10	42	42					1			1
62	Beland, *Muskogee*	1906	390	*x*	8,030					15			15
63	Boyle, *Muskogee*	1927	230	*y*	16,060					15			15
64	Boynton, *Muskogee*	1914	2,740	*x*	14,600					40			40
65	Butler, *Muskogee*	1918	1,500	*x*	29,565					64			64
66	Cole, *Muskogee*	1914	780	*x*	6,935					17			17
67	Council Hill, *Muskogee*	1919	335	*x*	39,055					30			30
68	Haskell, *Muskogee*	1909	1,750	*x*	33,580					78			78
69	Jolly-Patton, *Muskogee*	1920	260	*y*	0					20			20
70	Link, *Muskogee*	1909	715	*x*	58,035					34			34
71	Muskogee, *Muskogee*	1904	3,760	*x*	70,445					124			124
72	North, *Muskogee*	1906	290	*x*	0					24			24
73	Robinson, *Muskogee*	1915	280	*x*	0					2			2
74	Sheppard, *Muskogee*	1917	140	*x*	2,920					1			1
75	Sommerville, *Muskogee*	1926		*y*	0				Abandoned				
76	Transcontinental, *Muskogee*	1918	215	*x*	2,920					8			8
77	Yahola, *Muskogee*	1914	680	*x*	5,475					19			19
78	Miscellaneous, *Muskogee*		820	*x*	7,665					17			17
79	Baltimore, North, *Okfuskee*	1922	525	*y*	3,285					3			3
80	Bearden, *Okfuskee*	1924		*y*	0				Abandoned				
81	Beidleman, *Okfuskee*	1930	100	264,606	8,760					6			6
82	Blakley, *Okfuskee*	1924	110	843,046	11,315					3			3
83	Cary, *Okfuskee*	1923	485	1,105,322	31,390					11			11
84	Clearview, *Okfuskee*	1927	240	*y*	27,010					10			10
85	Cowan, *Okfuskee*	1940	50	18,161	6,205					2			2
86	Deaner, *Okfuskee*	1920	1,460	*y*	98,550					88			88
87	Fields, *Okfuskee*	1918	460	*x*	12,410					12			12
88	Gregory, *Okfuskee*	1922	160	*y*	26,280					13			13
89	Gypsy Hill, *Okfuskee*	1910	1,603	*x*	24,455					21			21
90	Haydenville, *Okfuskee*	1939	240	72,936	21,900					4			4
91	Josey, *Okfuskee*	1923	525	*y*	63,510					24			24
92	Keaton, *Okfuskee*	1919	210	*x*	0					2			2
93	Lyons-Quinn, *Okfuskee*	1921	1,645	*y*	52,195					23			23
94	Mason, *Okfuskee*	1940	40	8,329	4,745	2				2			2
95	Micawber, *Okfuskee*	1923	160	*y*	5,110					1			1
96	Morgan, *Okfuskee*	1923	340	*y*	2,920					1			1
97	Okemah, *Okfuskee*	1921	820	*y*	114,610		4			55			55
98	East, *Okfuskee*	1940	60	181,558	128,115	10	4			10			10
99	North, *Okfuskee*	1941	30	28,147	28,147	3	2			3			3
100	West, *Okfuskee*	1941	60	39,125	39,125	5	2			5			5
101	Okfuskee, *Okfuskee*	1938	60	113,494	17,155					5			5
102	Paden, *Okfuskee*	1914	80	*x*	7,665					3			3
103	Sheldon, *Okfuskee*	1916	900	*x*	43,435					18			18
104	Weleetka, *Okfuskee*	1913	1,815	*x*	239,805		4			75			75
105	South, *Okfuskee*	1937	30	57,450	2,555					3			3
106	West, *Okfuskee*	1926	140	693,111	221,920		5			15			15
107	Miscellaneous, *Okfuskee*		190	*x*	12,775					2			2
108	Aztec, *Okmulgee*	1917	2,140	*x*	28,105					70			70
109	Bald Hill, *Okmulgee*	1908	25,095	*x*	421,940					816			816
110	Beets-Rapp, *Okmulgee*	1920		*y*	0				Abandoned				
111	Beggs, North, *Okmulgee*	1909	1,840	*x*	23,725					35			35
112	Beggs, South, *Okmulgee*	1911	4,455	*x*	74,460					54			54
113	Brinton, *Okmulgee*	1914	545	*x*	14,235					17			17
114	Coalton, *Okmulgee*	1907	2,040	*x*	24,820					79			79
115	Edna, East, *Okmulgee*	1919	150	*x*	2,190					2			2
116	Eram, *Okmulgee*	1921	600	*y*	4,745					15			15
117	Hamilton Switch, *Okmulgee*	1909	2,570	*x*	33,580					78			78
118	Hector, *Okmulgee*	1914	645	*x*	1,825					10			10
119	Henryetta, *Okmulgee*	1910	785	*x*	10,950					47			47
120	Montezuma, *Okmulgee*	1918	220	*x*	6,205					4			4
121	Morris, *Okmulgee*	1907	7,300	*x*	135,780					266			266

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
60		35	Wilcox	Ord	S							
61												
62		35	1st and 2nd Dutcher	Pen	S							
63		38	Dutcher	Pen	S							
64		35	Mississippian	Mis	L							
65		32	Unidentified sand									
66		35	Unidentified sand									
67		38	Various	Pen								
68		34	Tucker	Pen								
69		33	Muskogee, Timber-Ridge									
70		36	Booch, Dutcher	Pen								
71		38	Unidentified sand, Wilcox	Ord	S		1,052	1,790				
72		35	Wilcox	Ord	S							
73		39	Muskogee									
74		39	Unidentified sand									
75												
76		39	Booch	Pen	S							
77		39	Booch, Boynton	Pen								
78		38	Leidecher, Dutcher, Wilcox	Pen, Ord								
79		38	Dutcher, 1st and 2nd Wilcox	Pen, Ord								
80												
81		38	Wilcox	Ord	S							
82		39	Unidentified sand									
83		32	Various	Pen								
84		38	Wilcox	Ord	S							
85		42	Hunton	Sil-Dev								
86		38	Deaner, Lyons, Wilcox	Pen, Ord	S		2,800	3,650				
87		43	Deaner, Wilcox	Pen, Ord	S							
88		39	Various	Pen, Ord								
89		33	Youngstown, Dutcher, Wilcox	Pen, Ord	S		2,430	3,290				
90		31	Dutcher, Wilcox	Pen, Ord	S							
91		40	Wilcox	Ord	S		3,600	3,650	50	D	Wilcox	3,700
92		39	Dutcher, Quin	Pen								
93		39	Lyons	Pen								
94		39	Hunton	Sil-Dev								
95		36	Wheeler, Dutcher	Pen								
96		37	Dutcher	Pen								
97		30	Gilcrease, Cromwell	Pen								
98		37	Lower Cromwell	Pen								
99		35	Gilcrease	Pen								
100		Dist.	Hunton	Sil-Dev			3,916	3,960	44			
101		39	Dutcher, Wilcox	Pen, Ord								
102		36	Prue	Pen	S							
103		42	Wilcox	Ord								
104		39	Gilcrease	Pen	S		2,530	2,660	130			
105		39	L. Gilcrease	Pen	S							
106		41	Booch	Pen	S							
107		36	Various	Pen, Ord								
108		38	Booch, Wilcox	Pen, Ord	S							
109		30	Glenn	Pen	S		750	2,250				
110												
111		38	Youngstown, Wilcox	Pen, Ord								
112		37	Various	Pen, Mis, Ord								
113		37	Wilcox	Ord	S							
114		30	Booch, Wilcox	Pen, Ord	S		1,300	2,835				
115		30	Unidentified sand									
116		40	Wilcox	Ord	S							
117		29	Glenn, Dutcher, Wilcox	Pen, Ord	S		1,385	2,700				
118		37	Various	Pen, Mis, Ord	S, L							
119		38	Various	Pen, Sil-Dev, Ord, Cam	S, L							
120		38	Unidentified sand									
121		36	Various	Pen, Mis, Ord	S, L		1,600	2,450				

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
			Oil	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells	
							Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift
122	Natura District, *Okmulgee*	1914	1,750	*x*	16,425					17			17
123	Nuyaka, South, *Okmulgee*	1937	105	470,358	46,355					6			6
124	Nuyaka, Southwest, *Okmulgee*	1941	40	14,735	9,125	2	2			2			2
125	Oklahoma Central, *Okmulgee*	1921	545	*y*	14,600					9			9
126	Okmulgee, *Okmulgee*	1906	5,020	*x*	60,590					151			151
127	Phillipsville, *Okmulgee*	1920	580	*y*	9,855					8			8
128	Pine, *Okmulgee*	1915	815	*x*	8,030					26			26
129	Pollyanna, *Okmulgee*	1921	3,975	*y*	132,130					223			223
130	Schulter, *Okmulgee*	1907	455	*x*	5,840					15			15
131	Simmons-Black, *Okmulgee*	1920	455	*y*	40,515					15			15
132	Spencer, *Okmulgee*	1917	790	*x*	19,345					34			34
133	Summers, *Okmulgee*	1914	290	*x*	3,650					14			14
134	Tiger Flats, *Okmulgee*	1928	1,045	*y*	1,095					6			6
135	Youngstown, *Okmulgee*	1915	2,235	*x*	35,770					47			47
136	Miscellaneous, *Okmulgee*		565	*x*	22,150					15			15
137	Airport, *Tulsa*	1937	330	139,874	4,015					53			53
138	Alsuma, *Tulsa*	1916	850	*x*	4,015					8			8
139	Bird Creek, *Tulsa*	1906	17,910	*x*	486,545					1,784			1,784
140	Bixby, *Tulsa*	1916	1,860	*x*	57,305					82			82
141	Broken Arrow, *Tulsa*	1901	3,665	*x*	32,850					74			74
142	Bruner Vern, *Tulsa*	1923	1,055	*y*	44,895					54			54
143	Collinsville, *Tulsa*	1916	120	*x*	4,015					12			12
144	Dawson, *Tulsa*	1906	765	*x*	12,410					49			49
145	Fisher, *Tulsa*	1918	685	*x*	4,745					7			7
146	Jenks, *Tulsa*	1901	6,885	*x*	89,425					348			348
147	Leonard, *Tulsa*	1916	1,000	*x*	23,360					32			32
148	Owasso, *Tulsa*	1913	360	*x*	8,030					24			24
149	Perryman, *Tulsa*	1924	345	*y*	1,095					11			11
150	Red Fork, *Tulsa*	1901	4,390	*x*	27,010					90			90
151	Sand Springs, *Tulsa*	1916	625	*x*	33,945					49			49
152	Tulsa, *Tulsa*	1901	910	*x*	730					7			7
153	Turkey Mountain, *Tulsa*	1922	1,115	*y*	35,770					49			49
154	Turley, *Tulsa*	1914	3,715	*x*	117,895					438			438
155	Wicey, *Tulsa*	1915	2,200	*x*	60,590					116			116
156	Bilby, *Wagoner*	1918	160	*x*	16,060					14			14
157	Corine, *Wagoner*	1919	190	*x*	2,555					9			9
158	Coweta, *Wagoner*	1914	720	*x*	13,140					46			46
159	George, *Wagoner*	1918	270	*x*	15,695					33			33
160	Gillette, *Wagoner*	1924	65	*x*	1,825					9			9
161	Goble, *Wagoner*	1916	325	*x*	8,760					20			20
162	Johnson-Bailey, *Wagoner*	1920	80	*y*	182					3			3
163	McCracken, *Wagoner*	1920	90	*y*	1,825					18			18
164	Oak Grove, *Wagoner*	1920	145	*y*	1,095					2			2
165	O.K., *Wagoner*	1919	80	*x*	0					9			9
166	Oneta, *Wagoner*	1916	695	*x*	32,485					61			61
167	Seltzer, *Wagoner*	1924	65	*y*	1,825					17			17
168	Stone Bluff, *Wagoner*	1915	1,065	*x*	136,145					177			177
169	Striker, *Wagoner*	1917		*x*	0				Abandoned				
170	Wagoner, *Wagoner*	1914	460	*x*	2,190					42			42
171	South, *Wagoner*	1939	80	6,858	2,920					3			3
172	Webster, *Wagoner*	1917	60	*x*	4,015					11			11
173	Wright, *Wagoner*		80	*y*	1,460					1			1
174	Miscellaneous, *Wagoner*		170	*y*	4,927					9			9
175	Aggregate for district of pools marked *x* or *y*			304,830,813									
176	Total East Central		148,368	308,887,965	4,056,648					6,785			

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
122		30	Various	Pen, Mis, Ord								
123		42	Wilcox	Ord	S							
124		38	Misener	Mis			3,168	3,176	8			
125		32	Wilcox	Ord	S							
126		30	Various	Pen, Mis, Ord	S		1,240	2,750				
127		45	Wilcox	Ord	S							
128		35	Booch, Dutcher	Pen	S							
129		34	Various	Pen, Ord, Cam	S, L		1,365	2,285				
130		36	Deaner, Glenn, Wilcox	Pen, Ord								
131		36	Salt, Booch	Pen								
132		33	Various	Pen, Mis, Ord, Cam								
133		38	Dutcher	Pen	S							
134		37	Various	Pen, Ord								
135		31	Youngstown	Pen	S							
136		40	Booch, Dutcher, Wilcox	Pen, Ord	S							
137		38	Bartlesville	Pen	S							
138		35	Burgess	Pen	S							
139		31	Bartlesville, Wilcox	Pen, Ord	S		1,110	1,345				
140		32	Various	Pen, Ord	S, L							
141		37	Various	Pen, Mis, Ord, Cam	S, L		1,350	1,500				
142		37	Various	Pen, Ord, Cam								
143		33	Various	Pen, Mis	S, L							
144		36	Bartlesville, Tucker	Pen	S							
145		34	Oswego, Tyner, Arbuckle	Pen, Ord, Cam								
146		36	Various	Pen, Mis Ord, Cam	S, L							
147		35	Various	Pen, Mis, Ord, Cam	S, L							
148		30	Various	Pen, Ord, Cam								
149		31	Unidentified sand									
150		34	Various	Pen, Ord, Cam			599	2,160				
151		37	Various	Pen, Ord, Cam								
152		34	Various	Pen, Mis, Ord								
153		35	Various	Pen, Ord, Cam								
154		32	Bartlesville, Burgess, Siliceous	Pen, Ord, Cam	S, L		1,260	1,945				
155		37	Various	Pen, Mis, Ord	S, L		1,480	1,950				
156		35	Dutcher, Burgess	Pen								
157		39	Unidentified sand									
158		38	Various	Pen, Mis, Ord, Cam	S, L		700	1,280				
159		36	Dutcher	Pen	S							
160		38	Tyner	Ord								
161		37	Dutcher	Pen	S							
162		33	Unidentified sand									
163		43	Tyner	Ord								
164		33	Pitkin, Burgen	Pen, Ord								
165		36	Dutcher, Tyner, Burgen	Pen, Ord								
166		38	Dutcher, Mississippi, Tyner	Pen, Mis, Ord	S, L		1,000	1,200				
167		37	Dutcher	Pen	S							
168		36	Various	Pen, Mis, Ord, Cam			1,840	2,275				
169			Dutcher, Morrow-Pitkin	Pen, Mis								
170		35	Peru, Ordivician	Pen, Ord								
171		36	Pennsylvanian									
172		33	Burgen	Ord								
173		39	Pitkin	Pen	L							
174		32	Unidentified sand and lime									
175												
176												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	EAST CENTRAL (CREEK COUNTY)												
177	Arno	1923	210	*y*	52,925		2			17			17
178	West	1940	52	61,981	45,990	8	7			5			5
179	Big Pond	1924	470	*y*	121,910					34			34
180	Bowden	1906	3,495	*x*	129,210					224			224
181	Bristow	1916	5,255	*x*	319,010					137			137
182	Bristow, North	1922	1,700	*y*	130,670					99			99
183	Bristow, West	1922	565	*y*	39,055					18			18
184	Bruce	1926	515	*y*	41,245					42			42
185	East	1939	100	*y*	10,220					9			9
186	Cushing	1912	24,940	359,359,577	3,245,215	3,668				1,781			1,781
187	Deep Fork	1920	3,345	*y*	124,465					132			132
188	Depew	1915	1,365	*x*	330,690		2			82			82
189	Donnelly	1924	730	*y*	101,835					36			36
190	Edna	1940	50	57,972	32,485					5			5
191	Glenn pool	1905	15,970	220,594,053	1,319,840					1,765			1,765
192	Independent	1908	1,320	*x*	49,275					38			38
193	Iron Post	1917	925	*x*	30,295					56			56
194	Kellyville	1934	3,600	*y*	165,345					221			221
195	Mannford (deep and shallow)	1922–37	4,650	*y*	359,525					253			253
196	Mercer	1923	80	283,762	8,395					3			3
197	Mounds	1915	1,580	*x*	45,625					51			51
198	Newby	1929	80	*y*	5,475					6			6
199	Olean	1921	340	*y*	26,645					18			18
200	Olive	1914	2,235	*x*	149,285					202			202
201	Olive, South	1940	20	1,446	730	1				1			1
202	Pickett-Prairie	1916	1,820	*x*	13,505					56			56
203	Poor Farm	1920	340	*y*	18,980					13			13
204	Red Bank	1918	370	*x*	23,725					8			8
205	Sapulpa	1909	1,790	*x*	72,635					110			110
206	South	1910	2,570	*x*	102,930					80			80
207	Slick	1913	6,585	*x*	407,705					170			170
208	Stroud, East	1940	50	507,373	489,830	45	44			45			45
209	Tibbens	1924	430	*y*	23,360					38			38
210	North	1940	40	40,825	34,675	4				4			4
211	Tuskegee	1924	310	*y*	6,205					9			9
212	East	1925	540	982,204	160,600					30			30
213	Walker	1923	390	*y*	48,545					24			24
214	West	1939	40	93,987	27,010					8			8
215	Wilcox	1919	1,375	*x*	165,345					58			58
216	Miscellaneous		350	*y*	42,533					16			16
217	Aggregate for district of pools marked *x* or *y*			192,807,683									
218	Total East Central (Creek County)		90,592	774,790,863	8,522,943					5,904			
	NORTHEASTERN OKLAHOMA												
219	Craig, Nowata, Rogers, and Washington Counties		104,670	353,953,830	6,265,225					15,255			15,255
	NORTHERN OKLAHOMA												
220	Barnes, *Garfield*	1918	185	*x*	10,950					10			10
221	Brown, *Garfield*	1930	85	424,109	16,790					4			4
222	Enid, *Garfield*	1940	20	37,524	26,645	2	1			2			2

TABLE I.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
177		36	Simpson	Ord								
178		40	Prue, Red Fork, Bartlesville, Wilcox	Pen, Ord								
179		32	Jones, Glenn, Dutcher, Wilcox	Pen, Ord	S							
180		32	Taneha	Pen								
181		35	Layton, Ft. Scott, Oswego, Red Fork, Bartlesville, Dutcher, Miss., Wilcox	Pen, Mis, Ord	S, L		2,700	3,200				
182		35	Layton, Ft. Scott, Oswego, Red Fork, Bartlesville, Dutcher, Miss., Wilcox	Pen, Mis, Ord	S, L							
183		35	Dutcher	Pen			3,152	3,155				
184		35	Layton, Ft. Scott, Oswego, Red Fork, Bartlesville, Dutcher, Miss., Wilcox	Pen, Mis, Ord								
185		37	Layton	Pen								
186		39	Various	Pen, Ord	S, L	Por			x	AF		
187		42	Layton, Peru, Prue, Dutcher	Pen								
188		32	Glenn, Dutcher, Wilcox	Pen, Ord	S		2,700	3,397				
189		37	Dutcher, 1st Wilcox	Pen, Ord								
190		35	Wilcox	Ord								
191	RP	34	Various	Pen, Ord								
192		35	Taneha, Wilcox	Pen, Ord	S		2,100	2,550				
193		36	Wheeler, Prue, Cleveland	Pen	S		2,420	2,475				
194		30	Peru	Pen	S							
195		34	Various	Pen, Ord	S, L		1,550	2,980				
196		41	Dutcher, Wilcox	Pen, Ord	S							
197		33	Red Fork, Glenn, Tucker, Dutcher, Wilcox	Pen, Ord	S		400	2,400				
198		34	Dutcher	Pen	S							
199		40	Layton, Peru, Wheeler, Skinner, Bartlesville	Pen	S							
200		36	Various	Pen	S							
201		38	Prue	Pen								
202		35	Glenn, Taneha, Wilcox	Pen, Ord								
203		34	Various	Pen								
204		36	Various	Pen, Ord								
205		34	Various	Pen, Mis, Ord	S, L		1,000	2,290				
206		36	Taneha, Dutcher, Wilcox	Pen, Ord								
207		32	Various	Pen, Mis, Ord			2,340	3,088			Wilcox	3,140
208		41	2nd Wilcox	Pen, Ord								
209		34	Various									
210		39	Wilcox	Ord								
211		38	Various	Pen, Ord								
212		39	Various	Pen, Mis, Ord								
213		35	Various	Pen, Mis, Ord	S, L							
214		37	Bartlesville	Pen	S							
215		35	Various	Pen, Ord								
216		39	Prue, Bartlesville, Wilcox	Pen, Ord	S							
217												
218												
219		36										
220		39	Tonkawa, Layton	Pen								
221		39	Wilcox	Ord	S							
222		40	Mississippian	Mis	L							

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
223	Garber, *Garfield*	1916	4,520	55,146,884	635,830	973				555			555
224	North, *Garfield*	1927	90	*y*	12,410					7			7
225	Hillsdale, *Garfield*	1938	70	86,705	6,935					1			1
226	Waukomis, *Garfield*	1938	30	35,044	120	1			Abandoned				
227	Miscellaneous, *Garfield*	1926	40	61,160	2,920					1			1
228	Caldwell, *Grant*	1929	80	266,483	5,475					2			2
229	Deer Creek, *Grant*	1922	210	1,297,997	62,780					11			11
230	Lamont, *Grant*	1937	60	724,658	168,265	3	1			2			2
231	Webb, *Grant*	1926	120	212,552	9,855					4			4
232	Blackwell, *Kay*	1918	1,750	5,152,119	155,125					41			41
233	Braman, *Kay*	1924	335	4,652,483	102,565		1			30			30
234	North, *Kay*	1924	795	18,239,242	268,275					52			52
235	Southeast, *Kay*	1938	200	277,034	129,210					6			6
236	Dilworth, *Kay*	1917	2,355	5,269,434	150,380		6			76			76
237	Hubbard, *Kay*	1924	645	8,384,128	159,870					36			36
238	Mervine, *Kay*	1913	960	*x*	12,775					2			2
239	Newkirk, *Kay*	1919	250	*x*	25,550					6			6
240	Ponca City, *Kay*	1917	1,445	6,412,239	98,185					40			40
241	Thomas, *Kay*	Prior to 1914	275	7,190,698	78,475					13			13
242	Tonkawa, *Kay*	1921	3,695	121,368,335	631,815	929				189			189
243	South, *Kay*	1921		*x*	0				Abandoned				
244	Vernon, *Kay*	1925	660	3,336,598	94,900					17			17
245	Miscellaneous, *Kay*		120	*x*	7,400					5			5
246	Crescent, *Logan*	1933	955	13,470,628	582,905	54				34			34
247	Guthrie, *Logan*	1941	220	778,446	778,446	28	28			28			28
248	Hull, *Logan*	1934	80	229,813	10,950					2			2
249	Langston, *Logan*	1934	340	1,453,787	474,500		2			14			14
250	South, *Logan*	1935	40	47,432	5,110					1			1
251	Lovell, *Logan*	1928	220	2,656,537	39,785					9			9
252	South, *Logan*	1934	120	284,324	172,645		7			7			7
253	West, *Logan*	1936		95,176	0	2			Abandoned				
254	Marshall, *Logan*	1927	740	11,777,035	48,910					22			22
255	Meridian, *Logan*	1938	120	155,262	11,315	7				3			3
256	Navina, *Logan*	1941	20	134	134	1	1			1			1
257	Seward, *Logan*	1936	40	74,408	10,950					1			1
258	Billings: Deep, *Noble*	1935	1,060	11,271,607	2,262,270	79				77			77
259	Shallow, *Noble*	1917	590	6,195,746	12,775					7			7
260	Lucien, *Noble*	1932	4,170	28,423,453	2,033,780	128				122			122
261	North, *Noble*	1936	430	936,070	114,245					12			12
262	Marathon, *Noble*	1935	80	138,341	2,098	Abandoned during 1941							
263	Otoe City, *Noble*	1930	35	145,333	69,715		2			3			3
264	Perry, *Noble*	1923	60	78,902	4,745					1			1
265	Polo, *Noble*	1934	510	4,070,046	299,300	37				28			28
266	Sams, *Noble*	1925	295	*y*	29,565					7			7
267	Aggregate for district of pools marked *x* or *y*			5,532,510									
268	Total Northern Oklahoma		29,120	326,390,416	9,837,643					1,491			
	OKLAHOMA CITY AREA												
269	Moore, *Cleveland*	1935	940	8,290,407	316,820	40				32			32
270	Noble, *Cleveland*	1938	30	61,898	25,550	2				1			1
271	Norman, *Cleveland*	1939	60	8,467	2,190					1			1
272	Britton, *Oklahoma*	1935	1,245	2,423,512	142,715					26			26
273	South, *Oklahoma*	1938	70	148,558	38,690	2				2			2
274	Edmond, *Oklahoma*	1930	1,440	18,025,917	1,213,260					83			83
275	Jones, *Oklahoma*	1939	60	82,589	42,705					3			3
276	Newalla, South, *Oklahoma*	1939	40	23,927	3,650					1			1
277	Nicoma Park, *Oklahoma*	1929	80	346,248	8,030	2				2			2
278	Oklahoma City, *Oklahoma*	1928	15,200	556,142,275	31,980,935	1,542	38			1,006			1,006
279	Miscellaneous, *Oklahoma*		40	25,146	25,146					3			3
280	Total Oklahoma City Area		19,205	585,578,944	33,799,691					1,160			

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
223		41	Various	Per, Pen, Ord	S, L	Por	1,100	4,200	y		y	y
224		44	Various	Pen, Ord								
225		39	1st and 2nd Wilcox	Ord	S		y	y			y	y
226		53	Marshall Zone		S	y	7,260	7,280	20		y	y
227		43	Wilcox	Ord	S	Por	y	y	6	A	y	y
228		40										
229		38	Various	Pen, Mis, Ord	S, L		2,900	4,175	y			
230		40	Wilcox	Ord	S	y	5,400	5,410	10		y	y
231		42	Various	Pen, Mis, Ord								
232		40	Various	Pen, Ord	S, L		1,600	3,440				
233		40	Various	Pen, Ord	S, L							
234		41	Various	Pen, Ord	S, L							
235		40	Arbuckle, Wilcox	Cam-Ord, Ord	S	y	y	y	y		y	y
236		40	Blackwell, Wilcox	Pen, Ord					y	A		
237		37	Various	Pen, Ord		Por	y	y	y	AF	y	y
238		39	Various	Pen								
239		40	Burbank, Mississippian	Pen, Mis								
240		38	Various	Pen, Mis, Ord	S, L		1,500	3,900		A		
241		41	Various	Per, Pen, Ord	S, L	Por			y	x		
242		42	Various	Pen, Mis, Ord	S, L	Por	2,660	4,075	y	x		
243			Endicott, Tonkawa, Wilcox	Pen, Ord								
244		40	Various	Pen, Mis, Ord	S, L				y	x		
245		39	Various									
246		41	Layton, Wilcox, 2nd Wilcox	Pen, Ord	S	23				AF		
247		46	Bartlesville, 2nd Wilcox	Pen, Ord			5,109 5,425	5,123 5,445	14 20			
248		40	Layton, Tonkawa, Wilcox	Pen, Ord	S	Por		4,800				
249		39	Wilcox	Ord	S	Por	5,100	5,145		A	Wilcox	5,190
250		40	Upper Simpson	Ord								
251		40	Tonkawa, Wilcox	Pen, Ord	S	y	y	y				
252		49	Layton	Pen								
253		40	2nd Wilcox	Ord	S	Por	y		y	y		
254		41	Tonkawa, Wilcox, L Simpson	Pen, Ord	S	y	y	y	y			
255		48	Wilcox	Ord	S	y	5,200	5,220	20			
256		37	1st Wilcox	Ord			6,220	6,250				
257		38	Simpson dolomite	Ord	D							
258		41	Wilcox	Ord	S	Por	4,250	y	y	A		
259		41	Various	Pen	S, L	Por			50	A		
260		42	Various	Pen, Ord	S, L	Por	y	5,200	y	y		
261		41	Wilcox	Ord	S	Por	y	y	y	y		
262		42	Wilcox	Ord	S	Por	y	y	34	A		
263		39	Layton, Wilcox	Pen, Ord	S	Por	3,284	3,314	30	y		
264		41	Tonkawa, Reagan	Pen, Ord								
265		41	Various	Pen, Ord	S	y	4,823	4,900	y	y		
266		42	Tonkawa	Pen	S		1,902	1,912	10			
267												
268												
269		41	Dolomite, U. Simpson, 2nd Wilcox	Ord								
270		39	2nd Wilcox	Ord	S		7,670	7,672	2			
271		38	Upper Simpson	Ord	y	y	y	y	y			
272		45	Simpson, 2nd Wilcox	Ord	S, D, L	Por				AF		
273		35	2nd Wilcox	Ord	S		6,738	6,766	28			
274		39	Simpson, Wilcox	Ord		Por				AF	Arbuckle	7,000
275		35	Cleveland	Pen	S	y	4,796	4,808	12		2nd Wilcox	5,998
276		35	Hunton	Sil-Dev	L		6,004	6,095	91		2nd Wilcox	6,610
277		36	Trosper	Pen	S	Por	6,157	6,168	11	ML		
278		37	Various	Pen, Ord	S, L	Por		6,700	y			
279												
280												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
			Oil	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells	
							Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	OSAGE COUNTY												
281	Almeda	1918	1,205	*x*	12,775					79			79
282	Atlantic	1924	1,330	*y*	306,965					90			90
283	Avant	1904	12,520	*x*	713,575					754			754
284	West	1905	3,555	*x*	75,190					165			165
285	Backius	1919	850	*x*	8,760					34			34
286	Bandwheel	1921	630	*y*	42,340					39			39
287	Barker	1932	240	*y*	52,925					11			11
288	Barnsdall	1916	3,620	*x*	75,555					205			205
289	Barnsdall, South	1921	1,125	*y*	30,660					85			85
290	Barnsdall, West	1922	1,665	*y*	205,860					111			111
291	Bartlesville	1904	16,335	*x*	17,885					81			81
292	Big Horse	1927	335	*y*	4,745					23			23
293	Birch Creek	1920	830	*y*	8,760					47			47
294	Boston	1904	770	*x*	121,180					37			37
295	North	1921	240	*y*	14,965					11			11
296	Bowring	1921	160	*y*	3,650					12			12
297	Branstetter	1928	420	*y*	26,645					25			25
298	Buell	1922	100	*y*	13,505					9			9
299	Bulldog	1920	465	*y*	37,960					32			32
300	Burbank (*Osage and Kay*)	1920	24,665	205,163,092	3,274,050	2,203				1,697			1,697
301	South	Or. 1926 Ext. 1934	4,465	30,775,796	2,753,925	287				223		*y*	*y*
302	Candy Creek	1920	1,420	*y*	72,270					56			56
303	Canyon Creek	1923	160	*y*	50,370					5			5
304	Country Club	1923	515	*y*	25,185					30			30
305	Dalton	1926	205	*y*	3,285					3			3
306	Dewey	1904	4,920	*x*	22,630					108			108
307	Domes	1917	3,740	*x*	81,760					199			199
308	Edgewood	1921	285	*y*	9,490					16			16
309	Elgin, South	1917	1,985	*x*	18,980					120			120
310	Enfisco	1921	290	1,043,947	11,680					5			5
311	Fairfax	1925	220	*y*	29,930					16			16
312	Falls Dome	1920	380	*y*	19,345					22			22
313	Flat Rock	1906	7,485	*x*	277,765					595			595
314	Flesher	1919	320	*x*	6,935					5			5
315	Foraker	1920		*y*	0				Abandoned				
316	Forty-five	1916	1,795	*x*	31,390					108			108
317	Frankfort	1920		*y*	0				Abandoned				
318	Gilliland	1919	770	*x*	17,155					16			16
319	Happy Hollow	1919	540	*x*	50,735					27			27
320	Hardy	1934	40	84,745	7,665					1			1
321	Hickory Creek	1914	2,220	*x*	38,325					154			154
322	South	1939	340	342,715	233,600					36			36
323	Hominy	1916	415	*x*	17,885					11			11

TABLE I.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
281		33	Bartlesville, Burgess, Mississippian	Pen, Mis								
282		39	Burgess, Siliceous	Mis, Ord, Cam	S, L		2,500 2,750	2,525 2,765	25 15			
283	RP	33	Bartlesville, Burgess	Pen	S		1,400 1,450	1,465 1,600				
284		32	Bartlesville, Burgess	Pen	S							
285		34	Bartlesville, Mississippian	Pen, Mis	S, L							
286		34	Various	Pen, Mis	S, L							
287		36	Various	Pen, Mis, Ord, Cam								
288		33	Peru, Bartlesville, Mississippian, Arbuckle	Pen, Mis, Cam	S, L		1,110 1,550	[y] 1,725	[y] 75			
289		33	Bartlesville, Burgess	Pen	S							
290		34	Bartlesville	Pen	S							
291		33	Various	Pen			650	1,265				
292		35	Bartlesville, Mississippian	Pen, Mis	S, L							
293		34	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
294		37	Various	Pen, Mis, Ord, Cam	S, L		1,500	2,620				
295		36	Wilcox, Arbuckle	Ord, Cam								
296		34	Layton, Peru, Oswego Mississippian	Pen, Mis	S, L							
297		40	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
298		37	Various	Pen, Mis	S, L							
299		34	Various	Pen, Mis	S, L							
300	RP	38	Layton, Burbank, Wilcox	Pen, Ord	S		2,700	2,850	60	ML	Granite	4,240
301	PM	38	Burbank, Skinner	Pen	S			2,850				
302		33	Bartlesville, Burgess	Pen	S							
303		39	Bartlesville, Burgess	Pen	S							
304		33	Various	Pen, Ord								
305		38	Bartlesville, Burgess	Pen	S							
306		33	Various	Pen	L, S		650	1,265				
307		36	Stray, Bartlesville, Mississippian	Pen, Mis	S, L		1,570 1,680 1,880	1,124 1,780 1,925	67 100 45			
308		35	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
309		33	Ramsey, Pennsylvanian, Oswego	Pen								
310		36	Stray, Oswego, Mississippian	Pen, Mis	S, L							
311		38	Oswego, Burbank, Wilcox	Pen, Ord	S	20–25			[y]	ML		
312		36	Oswego, Bartlesville, Burgess	Pen								
313	RP	34	Bartlesville, Burgess	Pen	S		1,110 1,345	1,205 1,365	95 20		Wilcox	1,667
314		35	Bartlesville, Mississippian	Pen, Mis								
315												
316		34	Oswego, Skinner, Bartlesville	Pen								
317			Pennsylvanian, Oswego, Mississippian	Pen, Mis	S, L							
318		36	Various	Pen, Mis, Ord, Cam	S, L							
319		36	Oswego, Bartlesville, Burgess	Pen								
320		39	Layton	Pen	S							
321		35	Oswego, Bartlesville, Mississippian	Pen, Mis	S, L							
322		36	Wayside									
323		34	Various	Pen, Mis, Ord, Cam	S, L		2,625	2,685	50	A	Arbuckle	3,206

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[e]	Producing Gas[e]	Flowing	Artificial Lift
324	Hominy, East	1918	630	*x*	20,440					21			21
325	Hominy, South	1940	30	9,420	6,935					3			3
326	Hominy Falls	1919	1,385	*x*	32,120					52			52
327	Kasishke	1921	140	*y*	9,490					17			17
328	Kaw	1922	180	199,104	44,165					7			7
329	Landon	1919	145	*x*	2,920					9			9
330	Lee Dome	1926	80	*y*	6,935					5			5
331	Madalene	1920	520	*y*	29,200					37			37
332	East	1923	400	*y*	14,235					35			35
333	Manion	1927	460	872,890	56,210					36			36
334	North	1920	910	*y*	64,240					59			59
335	Myers	1919	260	*x*	3,650					5			5
336	Naval Reserve	1933	3,290	17,011,438	1,091,350	254				233			233
337	Nelagoney	1919		*x*	0				Abandoned				
338	New England	1920	585	*y*	36,865					27			27
339	Ochelata, North	1910	1,560	*x*	54,385					87			87
340	Ohio-Osage	1932	195	*y*	3,650					24			24
341	Okesa	1904	1,210	*x*	4,745					19			19
342	Osage City	1904	3,805	*x*	270,100					229			229
343	East	1920	805	*y*	72,635					61			61
344	Osage-Hominy	1917	1,625	*x*	247,835					138			138
345	Page	1918	745	*x*	26,645					32			32
346	Pawhuska	1919	505	*x*	33,215					19			19
347	West	1919	180	*x*	4,380					6			6
348	Pearsonia	1919	180	*x*	93,075					20			20
349	Penn Creek	1922	160	*y*	11,315					2			2
350	Pershing	1918	5,595	*x*	114,975					281			281
351	Pettit	1923	285	*y*	27,375					18			18
352	Pioneer	1920	300	*y*	20,075					21			21
353	Pond Creek	1913	1,295	*x*	18,250					56			56
354	Prue	1926	475	*y*	6,570					12			12
355	Quapaw	1914	3,645	*x*	60,590					203			203
356	Ramona	1911	1,755	*x*	76,650					81			81
357	Skiatook	1911	715	*x*	17,520					27			27
358	Sunset	1919	295	*x*	2,190					10			10
359	Tidal-Osage	1918	1,975	*x*	82,125					106			106
360	Turkey Creek	1917		*x*	0				Abandoned				
361	West	1925	305	*y*	730		Abandoned during 1941						
362	Whitetail	1919	205	*x*	3,650					9			9
363	Wildhorse	1912	4,670	*x*	287,255					409			409
364	North	1919	360	*x*	19,345					21			21
365	South	1923	205	*y*	10,220					11			11
366	West	1940	20	48,782	39,785					3			3
367	Woolaroc	1917	2,525	*x*	58,400					158			158
368	Wynona	1917	3,475	*x*	88,695					157			157
369	Miscellaneous		1,900	*y*	168,808					102			102
370	Aggregate for district of pools marked *x* or *y*			322,031,068									
371	Total Osage County		153,555	577,582,997	12,172,198					8,171			

TABLE I.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
324		34	Bartlesville, Mississippian, Hominy, Arbuckle	Pen, Mis, Ord, Cam	S		2,160	2,210		A	Arbuckle	2,857
325		40	Oswego	Pen								
326		36	Various	Pen, Mis	S, L							
327		40	Burbank	Pen	S							
328		35	Prue, Skinner	Pen								
329		35	Peru, Oswego, Bartlesville	Pen								
330		36	Oswego, Bartlesville, Burgess	Pen								
331		35	Prue, Oswego, Bartlesville	Pen								
332		35	Bartlesville	Pen	S							
333		38	Layton, Oswego, Bartlesville, Burgess	Pen								
334		38	Bartlesville, Wilcox	Pen, Ord	S							
335		34	Layton, Burgess	Pen								
336		39	Burbank	Pen	S				y	y		
337												
338		34	Bartlesville, Burgess, Arbuckle	Pen, Ord, Cam								
339		34	Prue, Bartlesville	Pen	S							
340		37	Cleveland, Bartlesville	Pen	S							
341		34	Prue, Bartlesville, Mississippian	Pen, Mis	S, L							
342		37	Burbank, Burgess, Arbuckle	Pen, Ord, Cam	S, L							
343		37	Cleveland, Bartlesville	Pen	S		1,620 2,250	1,645 2,280	25 30		Mississippian	2,431
344		37	Layton, Oswego, Bartlesville, Burgess	Pen	S, L		y	y	y			
345		33	Various	Pen, Ord, Cam	S, L							
346		35	Bartlesville, Burgess, Burgen, Arbuckle	Ord								
347		36	Bartlesville, Burgess, Burgen, Arbuckle	Pen, Ord, Cam	S, L							
348		36	Layton, Oswego, Burgess, Mississippian	Pen, Mis	S, L							
349		35	Bartlesville, Mississippian	Pen, Mis	S, L							
350		35	Cleveland, Bartlesville	Pen	S		1,385 2,033	1,400 2,063	15 30	D		
351		36	Various	Pen, Ord, Cam	S, L		y	y	45	A	2nd Wilcox	
352		34	Various	Pen, Ord	S, L							
353		33	Various	Pen, Mis	S, L							
354		36	Prue, Bartlesville	Pen	S							
355		34	Oswego, Skinner, Bartlesville	Pen	S		1,720	1,780	60			
356		33	Big Lime, Bartlesville, Burgess	Pen	S, L							
357		34	Bartlesville, Burgess, Mississippian	Pen, Mis	S, L							
358		36	Bartlesville, Hominy, Arbuckle	Pen, Ord	S, L							
359		36	Burgess, Bartlesville	Pen	S							
360												
361		33	Pennsylvanian sand	Pen	S							
362		32	Stray, Bartlesville, Mississippian	Pen, Mis	S, L							
363		35	Various	Pen, Ord	S, L		3,550	4,260				
364		35	Various	Pen, Ord	S, L							
365		35	Various	Pen								
366		38	Arbuckle	Ord, Cam								
367		34	Skinner, Bartlesville	Pen	S							
368		35	Various	Pen, Mis	S, L		1,600	2,281				
369		35										
370												
371												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
	SEMINOLE AREA												
372	Adams, *Hughes*	1935	185	1,321,637	266,450	10				10			10
373	Alabama, *Hughes*	1923	640	y	36,500					22			22
374	Buchner, *Hughes*	1924	140	y	10,585					1			1
375	Calvin, *Hughes*	1938	80	95,111	36,500	5	2			5			5
376	Fish, *Hughes*	1934	1,320	17,135,463	1,329,695		17			142			142
377	Fuhrman, *Hughes*	1925	395	1,796,985	9,125					9			9
378	Gilcrease, *Hughes*	1924	245	420,162	2,190					2			2
379	Holdenville, North, *Hughes*	1926	80	137,211	1,825					1			1
380	Holdenville, West, *Hughes*	1916–30	1,340	5,123,692	215,350		2			113			113
381	Lamar, *Hughes*	1923		104,160	0			Abandoned					
382	Papoose, *Hughes*	1923	2,815	21,850,288	206,225	279				57			57
383	Spaulding, *Hughes*	1929	80	76,791	4,015		2			2			2
384	Wetumka, *Hughes*	1923	255	y	15,330					4			4
385	East	1938	80	96,513	55,480		3			5			5
386	South	1926	100	y	4,015		1			6			6
387	Yeager, *Hughes*	1925	345	1,984.400	25,915					6			6
388	North, *Hughes*	1936	100	131,578	22,995					7			7
389	Miscellaneous, *Hughes*		220	151,151	18,980					10			10
390	Castle, *Okfuskee*	1941	80	68,035	68,035	2	2			2		2	
391	North, *Okfuskee*	1941	120	17,648	17,648	3	3			3		3	
392	South, *Okfuskee*	1941	20	15,961	15,961	3	3			3		3	
393	Cromwell, East, *Okfuskee*	1940	250	1,444,759	1,284,800	62	50			56			56
394	Cromwell, North, *Okfuskee*	1938		562,197	363,175		1			15			15
395	Dill, *Okfuskee*	1931	1,060	4,334,166	1,440,655	94	35			87		y	y
396	Olympic, *Okfuskee*	1934	3,860	11,386,621	592,395	348				324			324
397	Rusk, *Okfuskee*	1941	40	138,116	138,116	8	8			8			8
398	Miscellaneous, *Okfuskee*		10	6,542	6,542					3			3
399	Asher, *Pottawatomie*	1929	430	3,625,435	44,165	70	1			5			5
400	West, *Pottawatomie*	1930	780	7,477,416	102,200					33			33
401	Avoca, *Pottawatomie*	1938	180	1,129,889	537,645	18	8			18			18
402	Earlsboro, West, *Pottawatomie*	1924–29	1,405	2,474,555	409,165		24			58			58
403	Gray, *Pottawatomie*	1932	240	4,355,577	362,445	35				26			26
404	Grisso, *Pottawatomie*	1934	210	352,532	23,360					3			3
405	Hotulke, West, *Pottawatomie*	1941	210	232,654	232,654	11	11			11			11
406	King, *Pottawatomie*	1939	100	121,541	15,695					3			3
407	West, *Pottawatomie*	1939	100	229,034	5,475					4			4
408	Maud, *Pottawatomie*	1928	1,980	12,074,104	212,795	156	1			58			58
409	South, *Pottawatomie*	1941	90	237,053	237,053	9	9			9			9
410	Prague, *Pottawatomie*	1940	160	558,932	400,770	17	5			17			17
411	Romulus, *Pottawatomie*	1940	380	913,332	808,840		16			18			18
412	Sacred Heart, *Pottawatomie*	1939	100	271,244	52,195					8			8
413	Shawnee, *Pottawatomie*	1934	520	2,833,196	468,660					53			53
414	East, *Pottawatomie*	1937	40	65,567	2,309		Abandoned during 1941						
415	North, *Pottawatomie*	1937	80	281,163	138,335					4			4
416	St. Louis, *Pottawatomie*	1927	19,865	154,433,278	6,479,480	1,214	38			878			878
417	East, *Pottawatomie*	1941	70	92,341	92,341	7	7			7			7
418	North, *Pottawatomie*	1941	170	330,506	330,506	19	19			19			19
419	Tecumseh, *Pottawatomie*	1937	40	139,107	20,440	1				1			1
420	East, *Pottawatomie*	1941	180	209,308	209,308	9	9			8			8
421	Tecumseh Lake, *Pottawatomie*	1941	100	482,534	482,534	12	12			12			12
422	Miscellaneous, *Pottawatomie*		110	y	3,650					3			3
423	Allen (deep), *Seminole*	1927	3,390	51,420,814	1,579,720	475	9			300			300
424	Bethel, *Seminole*	1925	620	1,818,878	54,750					35			35
425	North, *Seminole*	1936	300	3,708,779	607,360	32	2			27			27
426	Northeast, *Seminole*	1941	20	3,556	3,556	1	1			1			1
427	West, *Seminole*	1941	100	42,988	42,988	5	5			5			5

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
372		40	Misener	Mis	S	Por			15	A	Wilcox	4,317
373		39	Various	Pen								
374		35	Booch, Cromwell	Pen	S		y	y	y			
375		36	Viola	Ord	L		y	y	y			
376		37	Various	Pen, Ord			y	y	y			
377		37	Gilcrease, Cromwell	Pen	S		y	y	y			
378		39	Gilcrease	Pen	S		y	y	y			
379		40	Cromwell	Pen	S		3,418	3,437	19			
380		37	Various	Pen, Ord	S							
381		39										
382		36	Calvin, Gilcrease, Cromwell	Pen	S	Por			10	A	Wilcox	
383		35	Booch	Pen	S							
384		38	Various	Pen, Sil-Dev	S, L							
385		53	Hunton, 2nd Wilcox	Sil-Dev, Ord	S							
386		39	Gilcrease, Cromwell	Pen	S							
387		39	Various	Pen, Sil-Dev, Ord	S, L							
388		37	Cromwell, Hunton, 2nd Wilcox	Pen, Sil-Dev, Ord	S, L							
389		35	Booch, Cromwell	Pen	S							
390		43	Booch, Hunton	Pen, Sil-Dev			3,950	3,960				
391		41	Cromwell	Pen			3,310	3,323	13			
392		43	Hunton	Sil-Dev			3,930	3,942	12			
393		36	Cromwell, Hunton, Wilcox	Pen, Sil-Dev, Ord								
394		36	Booch, Cromwell	Pen	S							
395		36	Senora, Cromwell, Hunton	Pen, Sil-Dev	S, L	Por						
396		34	Senora, Cromwell	Pen	S	Por	3,433	3,475	y			
397		38	Cromwell	Pen			3,691	3,710				
398		35	Booch	Pen								
399		39	Wanette, Viola	Ord	S, L		y	y	y			
400		43	Wanette				3,450					
401		39	Viola, 2nd Wilcox	Ord	S,L							
402		38	Hunton	Sil-Dev	L		y	y	y			
403		40	Wanette, Hunton, Simpson	Sil-Dev, Ord			2,500	3,475	25	A	Wilcox	3,500
404		36	Hunton, Simpson	Sil-Dev, Ord	L						Wilcox	4,860
405		38	Viola, Wilcox	Ord								
406		41	Hunton, Viola	Sil-Dev, Ord	L		4,374	4 416	42			
407		41	Hunton	Sil-Dev	L		4,281	4,306	25			
408		38	Misener, Hunton, Simpson	Mis, Sil-Dev, Ord	S, L	Por	4,130	4,140	10	A	Wicox	4,330
409		40	Simpson	Ord	D		4,320	4,325	5			
410		34	Senora	Pen								
411		38	Hunton	Sil-Dev								
412		32	Earlsboro	Pen	S		2,862	2,883	21			
413		34	Earlsboro	Pen	S	Por			y	y		
414		31	Wilcox	Ord	S		4,839	4,844	5			
415		36	Simpson	Ord			4,853	4,886	33			
416		38	Various	Pen, Sil-Dev, Ord	S, L	Por	y	y	y	y		
417		37	Wilcox	Ord			4,111	4,119	8			
418		38	Hunton	Sil-Dev	L		3,863	3,879	16			
419		37	Simpson	Ord	D		5,125	5,238	113			
420		35	Viola, Wilcox	Ord			4,582 4,835	4,620 4,838	38 3			
421		38	1st Wilcox	Ord			5,234	5,244	10			
422		36	Earlsboro	Pen	S							
423		36	Various	Mis, Sil-Dev, Ord	S, L		2,500	4,250				
424		36	Booch, Gilcrease, Cromwell	Pen	S					ML		
425		40	Cromwell	Pen	S	Por			20	A	Cromwell	
426			Cromwell	Pen								
427		39	Cromwell	Pen			3,450	3,451				

Table 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
			Oil	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells	
							Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift
428	Bowlegs, *Seminole*	1926	4,000	119,124,423	2,156,785	364				210			210
429	West, *Seminole*	1941	20	0	0	1	1			1			1
430	Carr City, *Seminole*	1927	1,885	30,783,284	799,350	121				79			79
431	Cromwell, *Seminole*	1923	5,465	57,128,518	1,034,045	501	6			240			240
432	South, *Seminole*	1937	80	464,301	64,970	8				6			6
433	Dill, South, *Seminole*	1941	30	65,774	65,774	3	3			4			4
434	Dora, *Seminole*	1935	1,110	4,666,285	440,920		2			110			110
435	Earlsboro, *Seminole*	1926	5,235	125,474,833	1,351,595	497				172			172
436	East, *Seminole*	1929	2,105	38,701,197	597,140	187	2			82			82
437	North, *Seminole*	1936	460	5,120,234	1,244,650	36				36			36
438	South, *Seminole*	1930	430	8,842,861	216,445		5			22			22
439	Fish, West, *Seminole*	1941	10	8,253	8,253	1	1			1			1
440	Grayson, *Seminole*	1935	530	1,858,903	275,940					34			34
441	Hazel, *Seminole*	1938	220	423,693	55,115	21				19			19
442	Jackson, *Seminole*	1925	735	738,620	29,565					11			11
443	Keokuk, *Seminole*	1933	2,585	11,587,645	1,028,935	107				98			98
444	Konawa, *Seminole*	1929	1,695	15,213,015	359,525	124	4			96			96
445	East, *Seminole*	1936	225	203,955	8,760					6			6
446	South, *Seminole*	1938	140	979,166	719,050		26			44			44
447	West, *Seminole*	1938	170	559,788	113,880	16	1			17			17
448	Little River, *Seminole*	1927	4,000	111,719,540	2,241,100	601	6			232			232
449	East, *Seminole*	1928	910	16,718,070	230,680		1			62			62
450	North, *Seminole*	1941	180	140,069	140,069	5	5			5			5
451	Southeast, *Seminole*	1940	40	11,180	5,840	2				2			2
452	West, *Seminole*	1938	270	818,475	195,640		4			16			16
453	Mission, *Seminole*	1928	1,570	25,502,275	447,125	122				63			63
454	Rosanna, *Seminole*	1924	505	*y*	144,905		1			21			21
455	Sancho, *Seminole*	1929	60	333,624	17,885					6			6
456	Sasakwa, *Seminole*	1927	1,145	10,845,475	334,705	106	4			61			61
457	Sasakwa Townsite, *Seminole*	1933	175	2,335,399	102,200					8			8
458	Searight, *Seminole*	1926	2,110	34,258,399	393,105	144				58			58
459	East, *Seminole*	1939	80	168,563	21,170					4			4
460	North, *Seminole*	1934	381	3,498,633	243,090	19				13			13
461	Seminole City, *Seminole*	1926	4,635	128,839,681	2,230,880	401	5			199			199
462	Seminole: East, *Seminole*	1926	1,545	8,526,802	331,055	132				93			93
463	North, *Seminole*	1940	70	49,305	42,705					7			7
464	West, *Seminole*	1935	260	13,211,924	700,800	40	10			34			34
465	Swan, *Seminole*	1938	10	13,764	2,190					1			1
466	Sylvian, *Seminole*	1941	40	4,511	4,511	1	1			1			1
467	Transco, *Seminole*	1926	40	104,143	0				Abandoned				
468	Traugh: Deep, *Seminole*	1937	140	859,130	117,165	16				14			14
469	Shallow, *Seminole*	1937	250	843,009	85,775	27				24			24
470	Tyrola, *Seminole*	1937	100	75,012	9,490	5				4			4
471	Wetley, *Seminole*	1927	360	512,992	36,500		1			18			18
472	Wewoka, *Seminole*	1923	2,015	40,120,532	338,720	234	2			85			85
473	East, *Seminole*	1927	180	1,801,485	73,000	30	1			8			8
474	North, *Seminole*	1940	50	133,325	110,595	4	2			5			5
475	Northeast, *Seminole*	1941	20	388,608	4,745	3	3			3			3
476	Wewoka Townsite, *Seminole*	1924	345	3,164,739	136,510	40				27			27
477	Wofford, *Seminole*	1935	50	652,505	20,075					3			3
478	Miscellaneous, *Seminole*		90	123,076	26,358					12			12
479	Aggregate for district of pools marked *x* or *y*			3,462,151									
480	Total Seminole Area		94,586	1,149,495,644	39,508,181					4,904			

TABLE I.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
428		40	Various	Pen, Sil-Dev, Ord	S, L	Por			30	A		
429		43	Hunton	Sil-Dev			4,354	4,390				
430		40	Misener, Hunton, Wilcox	Mis, Sil-Dev, Ord	S, L	Por	4,180	4,205		A	Wilcox	4,210
431		37	Various	Pen, Ord	S	Por		3,400		AF	Wilcox	4,226
432		37	Wapanucka-Cromwell, Wilcox	Pen, Ord	S		4,176	4,189	13			
433		40	Hunton	Sil-Dev			4,128	4,150	22			
434		35	Boggy, Calvin	Pen	S		2,947	2,959				
435		38	Earlsboro, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L		y	y	y			
436		39	Calvin, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L		y	4,250	y			
437		41	Hunton, Wilcox	Sil-Dev, Ord	S, L					A	Wilcox	4,680
438		39	Calvin, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L	Por	4,200	4,225	25	A	Wilcox	4,225
439		36	Booch	Pen			3,168	3,192	24			
440		40	Simpson	Ord		y	4,030	4,050	20	y	y	y
441		36	Thurman, Boggy	Pen	S		2,991	3,003	12	y		
442		38	Booch	Pen	S		y	y	y			
443		40	Misener, Hunton, Wilcox	Mis, Sil-Dev, Ord	S, L	y			y	y	Wilcox	4,483
444		36	Earlsboro, Cromwell, Simpson	Pen, Ord	S		y	y				
445		39	Earlsboro	Pen	S		y	y	y			
446		37	Hunton, Viola, Wilcox	Sil-Dev, Ord	S, L							
447		36	Boggy, Calvin	Pen	S		2,697	2,714	17			
448		38	Various	Pen, Ord	S	Por	y	4,100	y	y		
449		36	Various	Pen, Ord	S	y	y	y	y	y		
450		41	Hunton, Dolomite, Wilcox	Sil-Dev, Ord			4,282	4,289	7			
451		38	Senora	Pen								
452		39	Wilcox	Ord	S		4,378	4,380	2			
453		39	Hunton, Wilcox	Sil-Dev, Ord	S, L		y	4,300	y			
454		38	Booch	Pen	S		3,034	3,054	20			
455		37	Gilcrease, Cromwell	Pen	S							
456		36	Various	Pen, Ord	S, L		2,793	4,187				
457		37	Wilcox	Ord	S	Por	4,047	4,050	3	y		
458		38	Hunton, Wilcox	Sil-Dev, Ord	S, L	Por	4,120	4,325	y	y		
459		39	Cromwell	Pen	S		3,775	3,791	16	y		
460		32	Wilcox	Ord	S	y	4,596	y	y	y		
461		39	Various	Pen, Mis, Sil-Dev, Ord	S, L	Por				y	y	
462		38	Cromwell, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L			3,514				
463		31	Senora	Pen								
464		42	Calvin, Wilcox	Pen, Ord	S	Por	4,085	4,115	30	A	Wilcox	4,150
465		36	Thurman		S		2,671	2,691	20			
466		34	1st Wilcox	Ord			4,366	4,384	18			
467		36	Calvin, Senora	Pen			2,159	2,174	15			
468		36	Simpson, Wilcox	Ord	S			y	y			
469		33	Earlsboro	Pen	S		2,347	2,360	13			
470		37	Hunton	Sil-Dev	L		3,317	y	y			
471		35	Hunton	Sil-Dev	L		2,420	2,585	165			
472		37	Cromwell, Hunton, Wilcox	Pen, Sil-Dev, Ord	S, L	Por						
473		38	Hunton, Wilcox	Sil-Dev, Ord	S, L		4,214	y	y			
474		41	Wilcox	Ord								
475		36	Misener, Hunton	Miss, Sil-Dev			3,940	3,995				
476		38	Various	Pen, Sil-Dev, Ord	S, L							
477		40	Boggy, Wilcox	Pen, Ord	S		y	y	y			
478		38	Senora, Calvin, Hunton	Pen, Sil-Dev	S, L							
479												
480												

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift
	SOUTHEASTERN OKLAHOMA												
481	Brock, *Carter*	1922	765	3,525,832	92,710					127			127
482	Caddo, *Carter*	1939	40	33,768	10,585					1			1
483	Centrahoma, *Coal*	1937	80	88,098	20,075	3				3			3
484	Clarita, *Coal*	1937	40	66,047	11,315	4				3			3
485	Miscellaneous, *Coal*	1940	10	1,320	1,320					1			1
486	Miscellaneous, *Garvin*	1936		15,364	0					1			1
487	Citra, *Hughes*	1937	20	6,130	0	1				1			1
488	Miscellaneous, *Love*	1937	40	4,197	240					1			1
489	Byars, *McClain*	1939	130	331,565	44,165					6			6
490	Cumberland, *Marshall*	1940	380	2,789,287	2,362,645	42	29			43		43	
491	Enos, *Marshall*	1933	265	149,695	13,140					23			23
492	Isom Springs, *Marshall*	1931	380	171,137	21,900		7			54			54
493	Kingston, *Marshall*	1932	115	16,407	0					9			9
494	Madill, *Marshall*	1925	275	1,111,265	14,235					73			73
495	Miscellaneous, *Marshall*	1932	20	*y*	0					1			
496	Ada, East, *Pontotoc*	1928	225	260,115	23,725		1			18			18
497	Allen (shallow), *Pontotoc*	1913	2,530	8,714,748	128,115					195			195
498	Bebee, *Pontotoc*	1923	2,530	11,991,306	1,468,760		4			230			230
499	East, *Pontotoc*	1930	215	392,114	46,355					22			22
500	Conservation, *Pontotoc*	1927	285	508,468	24,455					12			12
501	Fitts, *Pontotoc*	1933	5,955	93,093,495	4,221,225	989				730			730
502	North, *Pontotoc*	1934	150	535,698	30,660					15			15
503	South, *Pontotoc*	1937	205	423,914	63,875					23			23
504	West, *Pontotoc*	1937	175	410,727	55,115					11			11
505	Francis, *Pontotoc*	1918	60	*x*	0					1			1
506	West, *Pontotoc*	1917	80	*x*	5,475		4			7			7
507	Jesse, *Pontotoc*	1935	1,035	4,955,751	709,925		1			62			62
508	Oakman, *Pontotoc*	1935	60	25,855	2,555		5			5			5
509	Steedman, *Pontotoc*	1920	50	23,310	0					1			1
510	North, *Pontotoc*	1928	305	1,655,282	82,125					14			14
511	Miscellaneous, *Pontotoc*		60	8,648	305					2			2
512	Aggregate for district of pools marked *x* or *y*			231,162									
513	Total Southeastern Oklahoma		16,480	131,540,705	9,455,000					1,695			
	SOUTHWESTERN OKLAHOMA												
514	Sayre, *Beckham*	1923		304,519	0			Abandoned					
515	Apache, *Caddo*	1941	80	174,875	174,875	9	9			9		9	9
516	Binger, *Caddo*	1934	80	80,922	9,855	1				1			1
517	Cement, *Caddo*	1917	4,505	22,909,621	3,374,060	478	47			362		*y*	*y*
518	Ed Cox, *Carter*	1925	770	727,364	81,030		10			45			45
519	Fox, *Carter*	1917–35	1,100	14,594,594	396,755					97			97
520	Graham, *Carter*	1917	2,990	26,417,977	367,190					258			258
521	Healdton *Carter*	1913	7 550	190,549,567	3,082,425	2,362	9			1,898			1,898
522	Hewitt, *Carter*	1919	4,530	92,510,511	4,530,380	1,094	115			908			908
523	Sholem Alechem, *Carter*	1923	4,760	37,876,464	908,850	401	1			311			311
524	Tatums, *Carter*	1927	2,660	16,180,615	612,835	247				217			217
525	Tussy, *Carter*	1933	985	4,375,699	1,303,050		17			102			102
526	Wheeler, *Carter*	1916	755	*x*	10,585					72			72
527	Wildcat Jim, *Carter*	1914	1,235	*x*	168,630					88			88
528	Miscellaneous, *Carter*		40	1,073	155					1			1
529	Hanbury, *Comanche*	1920	280	*y*	1,460					5			5
530	Lawton, *Comanche*	1915	960	*y*	4,745					95			95
531	Walters, *Cotton*	1917	3,790	25,434,979	311,710		1			242			242
532	Robberson, *Garvin*	1921	2,410	15,179,035	320,105	328				176			176
533	Knox, *Grady*	1924	1,990	15,001,207	642,035	269	8			176			176
534	Miscellaneous, *Grady*	1923	40	*y*	0					1			1
535	Altus, *Jackson*	1934	1,740	1,544,418	338,720		18			116			116
536	Tipton, *Jackson*	1935	750	1,675,138	219,000					56			56
537	Oscar, *Jefferson*	1924	685	964,097	448,950		3			189			189

TABLE I.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
							Top Prod. Zone	Bottoms Prod. Wells				
481		32	Ordivician, Arbuckle	Ord, Cam	S	Por		2,100		AF	Ord Lime	3,000
482		35	Woodford	Mis	S		4,170	4,324	154			
483		38	McAlester sand, Viola	Pen, Ord	S, L		5,970	6,235	265			
484		39	Atoka		S		790	836	46			
485			Cromwell	Pen			1,835	1,900				
486												
487		34	Bromide, McLish	Ord	S		5,755	5,994	*y*			
488		34										
489		37	Layton, Viola	Pen, Ord	L		3,485	3,623	138			
490		37	Bromide, McLish	Ord								
491		26	Preston, Arbuckle	Ord, Cam								
492		26	Stray sand		S		537	540	3			
493		26	Cretaceous, Trinity									
494		40	Bilbo, Arbuckle	Ord, Cam	S		402					
495												
496		27	Boggy, Senora	Pen	S		1,790	1,795	5			
497		30	Allen									
498		36	Boggy, Hunton, Viola	Pen, Sil-Dev, Ord								
499		35	Senora, Hunton, Viola, Simpson	Pen, Sil-Dev, Ord	S, L							
500		30	Boggy, Hunton	Pen, Sil-Dev							Wilcox	3,062
501		39	Various	Pen, Sil-Dev, Ord	S, L							
502		32	McAlester, Gilcrease	Pen	S		1,767	*y*	*y*			
503		35	Gilcrease, Hunton, Viola	Pen, Sil-Dev, Ord	S, L							
504		39	Cromwell	Pen	S		3,021	3,110	89			
505		26	Allen, Senora	Pen			1,200	2,000				
506		27	Allen, Senora	Pen								
507		40	Hunton, McLish	Sil-Dev, Ord	L, S							
508		29	Boggy	Pen	S		1,160	1,169	9			
509		31	Boggy	Pen								
510		31	Boggy	Pen								
511			Hunton	Sil-Dev	L							
512												
513												
514		34	Deese	Pen	S	Por		*y*	*y*			
515		39	Simpson	Ord			3,395	3,430				
516		38	Deese	Pen								
517		34	Various	Per, Pen	S		1,900	1,600				
518		22	Pontotoc, Deese	Pen			1,250	2,910	30			
519		31	Fox sand, Simpson, Oil Creek	Pen, Ord	S		2,200	2,500		A		
520		31	Deese	Pen	S	28–30				A	Dornicks Hills	5,180
521		31	Various	Pen, Ord	S, L		920	3,500		AF	Arbuckle	*x*
522		34	Hewitt, Viola	Pen, Ord	S	15–20	920	2,700		AF	Arbuckle	*x*
523		29	Hoxbar, Deese	Pen	S	30	1,890	4,000		A		
524		27	Deese, Arbuckle	Pen, Ord	S	30			60			
525		23	Deese	Pen	S	Por			*y*	A		
526		20	Pontotoc	Pen	S	*y*				A		
527		24	Pontotoc, Deese	Pen			1,552	2,890				
528		20										
529		38	Various	Pen	Gw, S		1,640	2,100				
530		30										
531		34	Cisco, Hoxbar				2,100	2,400				
532		23	Pontotoc, Simpson	Pen, Ord	S, L	*y*	1,200	1,900		A		
533		35	Pontotoc	Pen	S	15–20	1,700	2,200	15	AF		8,963
534			Pontotoc	Pen								
535		41	Granite wash	Pen	Gw	Por			30	D		
536		40	Canyon, Arbuckle	Ord	L		*y*	*y*	*y*			
537		33	Glenn	Pen	S		1,180	1,610	25			

initial capacity of 2,165,000,000 cu. ft., and 697 were dry holes.

Recompleted wells in the state—i.e., wells either plugged back or drilled deeper to test new horizons—were divided as follows: 283 oil wells with a combined initial production of 56,968 bbl., 34 gas wells aggregating 100,000,000 cu. ft., and 124 abandonments.

The state's wildcat effort met with meager success, although the total number of wells drilled increased 45 per cent from 227 in 1940 to 329 in 1941. Of these, 61 were oil wells; 25, gas wells; and 243, dry holes. The reworking of old producing areas was largely responsible for the discovery of numerous small pools with so high a rate of drilling. With the possible exception of the Apache pool, the discovery of which has revived interest in the Anadarko Basin, no new areas were provided where widespread exploitation can be expected. The principal new pools discovered as a result of the exploratory drilling were Apache, in Caddo County; Guthrie, in Logan County; and West Hotulke, Tecumseh Lake and North St. Louis, in Pottawatomie County. At the end of the year the Apache field had nine completed wells, which averaged 5009 bbl. initial from the Simpson Bromide formation at 3400 ft.; Guthrie had 28 wells with an average initial of 812 bbl. in the second Wilcox sand at 5485 ft.; West Hotulke had 11 wells with an initial average of 174 bbl. from the Wilcox

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
							During 1941		End of 1941			Number of Wells	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^e	Flowing	Artificial Lift
538	Seay, *Jefferson*	1924	325	529,545	16,790					49			49
39	Spring, *Jefferson*	1924	265	*y*	145,635					37			37
540	Hobart, *Kiowa*	1939	140	959,424	868,335		23			30			30
541	Stockton, *Love*	1937	40	49,088	8,760					1			1
542	Comanche, Stephens	1918	925	10,397,271	182,865		3			161			161
543	Cruce, *Stephens*	1926	100	*y*	6,935					5			5
544	Doyle, *Stephens*	1921–37	315	*y*	155,855		2			36			36
545	West, *Stephens*	1939	100	93,440	35,040					3			3
546	Duncan: North, *Stephens*	1920	1,260	4,226,878	135,415					92			92
547	West, *Stephens*	1919	910	5,897,342	115,705					71			71
548	Empire, *Stephens*	1920	2,630	*y*	655,175		13			282			282
549	Loco, *Stephens*	1915	575	1,520,476	56,575		4			63			63
550	West, *Stephens*	1941	40	0	0	6	6			6			6
551	Milroy: Deep, *Stephens*	1937–39	40	425,867	109,135	1				1			1
552	Shallow, *Stephens*	1916	800	3,354,691	109,500		2			142			142
553	Palacine, *Stephens*	1929	120	165,370	18,250					4			4
554	Rainola, *Stephens*	1921	150	*y*	35,405					23			23
555	Velma, *Stephens*	1917	3,610	6,122,431	312,075		32			648			648
556	Woolsey, *Stephens*	1922	170	*y*	21,900					19			19
557	Miscellaneous, *Stephens*		100	35,201	9,323					3			3
558	Frederick, *Tillman*	1937	40	26,882	730		11			3			3
559	West, *Tillman*	1937–39	180	2,144,528	947,905					30			30
560	Red River Bed, *Tillman*	1920	500	*y*	110,230					90			90
561	Aggregate for district of pools marked *x* or *y*			47,778,432									
562	Total Southwestern Oklahoma		58,020	550,229,541	21,364,938					7,224			
563	Total Oklahoma		760,454	4,929,220,502	152,117,398		See Table 2			54,442			

sand at 4600 ft.; Tecumseh Lake had 12 wells initially averaging 378 bbl. from the Wilcox sand at 5250 ft.; and North St. Louis had 19 wells, which averaged 432 bbl. initially from the Hunton limestone at 3850 ft.

MOST IMPORTANT DEVELOPMENT IN POOLS DISCOVERED PRIOR TO 1941

East Cromwell.—In the East Cromwell pool, 48 oil wells were drilled, with an average initial production of 507 bbl.; two gas wells, with an average of 725,000 cu. ft. of gas; and four dry holes. Reconditioning of four oil wells resulted in an aggregate of 1112 bbl. initial potential. The pool, discovered in 1940, averaged 3520 bbl. per day from the Cromwell and Wilcox sands at approximately 3500 and 4500 ft., respectively.

Dill Pool.—The original Hunton limestone discovery well in the Dill pool was completed in the early part of 1931 and production was discovered in the Cromwell sand in 1934. During 1941 some 35 oil wells were completed, with an average initial potential of 330 bbl. Production of the pool for the year averaged 3947 bbl. per day from a total of 87 producing wells.

Fish Pool.—Discovered in 1934, the Fish pool had 17 oil-well completions during 1941, with an average initial potential of 158 bbl., and eight dry holes. Production as a result of the additional development increased from 2,700 bbl. daily at the

TABLE 1.—(*Continued*)

Line Number	Repressuring Operation[d]	Character of Oil: Gravity A.P.I. at 60°F., Weighted Average	Producing Formation: Name	Producing Formation: Age[e]	Producing Formation: Character[f]	Producing Formation: Porosity[g]	Depth, Avg. Ft.: Top Prod. Zone	Depth, Avg. Ft.: Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Deepest Zone Tested to End of 1941: Name	Deepest Zone Tested to End of 1941: Depth of Hole, F
538		35	Cisco, Hoxbar				1,100					
539		35	Hoxbar				2,095	2,101	6			
540		35	Pontotoc, Conglomerate	Pen	L		1,091	1,107	16			
541		36	Unidentified		S		6,893	6,927	34			
542		34	Stray, Wilson, Pace		S		1,400	1,800				
543		30	Upper Penn.	Pen	S		800	1,900				
544		30	Permian, Hoxbar, Deese				1,100	1,250				
545		42	Deese	Pen	S		5,578	5,614	36			
546		36	Thomas				1,700	2,300				
547		33	Brown, Blaydes				1,700	2,300				
548		39	Various				1,600	2,300				
549		23	Pontotoc, Deese	Pen	S		850	1,550				
550		34	Sandy Lime				1,113	1,135				
551		42	Hunton, Oil Creek	Sil-Dev			7,554	7,625	71			
552		26	Pontotoc	Pen								
553		36	Pennsylvanian, Arbuckle	Pen, Ord								
554		36	Smith, Brown	Pen								
555		26	Permian, Glenn, Bromide	Per, Pen, Ord	S							
556		32	Permian, Glenn	Per, Pen								
557		36	Deese	Pen	S							
558		39	Canyon, Strawn	Ord	L, S		3,081					
559		37					4,215	4,218	3			
560		39	Cisco				1,540	1,700	19			
561												
562												
563												

TABLE 2.—*Summary of Drilling Operations in Oklahoma*

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day	Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Sec.	Twp.	Rge.					Oil, U. S. Bbl.		Cas-ing	Tub-ing	
1	Caddo	2	5 N	12 W	3,433	Permian	Bromide (Ord.)	The Texas Co.	1,434		420[a]	20[a]	
2	Logan	7	17 N	1 W	5,445	Permian	2nd Wilcox (Ord.)	Sunray et al.	2,444			300[a]	
3	Logan	12	17 N	2 W	5,505	Permian	2nd Wilcox (Ord.)	Sunray et al.	120	½			PB 5,175 ft.
4	Pottawatomie	27	8 N	4 E	4,346	Pennsylvanian	Dolomite (Ord.)	Amerada	524	½			PB 3,935 ft.
5	Osage	34	22 N	7 E	3,065	Pennsylvanian	Hominy (Ord.)	Devonian Oil	200				
6	Pottawatomie	21	9 N	4 E	4,644	Pennsylvanian	1st Wilcox (Ord.)	C. W. Sharpe et al.	500				PB 4,597 ft.
7	Pottawatomie	22	9 N	4 E	4,647	Pennsylvanian	2nd Wilcox (Ord.)	Atlantic	558				
8	Pottawatomie	16	9 N	4 E	4,722	Pennsylvanian	1st Wilcox (Ord.)	Atlantic & Crosbie	383	1			PB 4,652 ft.; Viola Wilcox
9	Pottawatomie	16	9 N	4 E	4,899	Pennsylvanian	2nd Wilcox (Ord.)	Atlantic	198				
10	Pottawatomie	36	10 N	3 E	5,245	Pennsylvanian	1st Wilcox (Ord.)	Hall & Jordan	1,078	1	75[a]		
11	Pottawatomie	32	8 N	5 E	4,330	Pennsylvanian	Wilcox (Ord.)	Kerlyn	181				PB 4,325 ft.
12	Seminole	30	8 N	7 E	4,170	Pennsylvanian	Hunton (Sil.-Dev.)	W. A. Delaney et al.	325	1			
13	Seminole	30	8 N	7 E	4,289	Pennsylvanian	Wilcox (Ord.)	Atlantic & Delaney	188	⅝			
14	Okfuskee	7	11 N	8 E	3,710	Pennsylvanian	Cromwell (Ord.)	D. B. Malernee	723	48/64			
15	Logan	17	15 N	3 W	6,422	Permian	2nd Wilcox (Ord.)	Continental et al.	192				PB 6,250 ft.
16	Stephens	35	1 S	5 W	7,808	Permian	Simpson (Ord.)	Skelly	200				
17	Oklahoma	32	14 N	3 W	6,325	Permian	Bartlesville (Pen.)	Harper & Turner					Dry and abandoned
18	Bryan	18	6 S	12 E	2,033	Cretaceous	Arbuckle Ls. (Cam. and Ord.)	Sinclair Prairie					Dry and abandoned
19	Logan	7	16 N	2 W	5,927	Permian	2nd Wilcox (Ord.)	Harry Miller					Dry and abandoned
20	Logan	11	17 N	2 W	5,695	Permian	2nd Wilcox (Ord.)	Deep Rock					Dry and abandoned
21	Love	12	7 S	2 E	4,935	Cretaceous	Woodford (Mis.)	Magnolia					Dry and abandoned
22	Garfield	8	23 N	4 W	6,339	Permian	2nd Wilcox (Ord.)	Gulf et al.					Dry and abandoned
23	Jackson	30	2 N	22 W	6,515	Permian	Canyon (Ord.)	Fain-Porter Drlg.					Dry and abandoned
24	Logan	13	17 N	2 W	5,577	Permian	2nd Wilcox (Ord.)	Big Chief Drill. et al.					Dry and abandoned
25	Logan	12	16 N	1 W	5,690	Permian	2nd Wilcox (Ord.)	Carter					Dry and abandoned
26	Carter	5	4 S	2 W	3,009	Permian	Hoxbar (Pen.)	Wirt Franklin					Dry and abandoned
27	Grady	31	5 N	8 W	6,446	Permian	Hoxbar (Pen.)	Tom Palmer					Dry and abandoned
28	Cimarron	35	2 N	8 ECM	6,168	Tertiary	Arbuckle (Cam. and Ord.)	Gulf					Dry and abandoned

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1941	215	45
Number of oil wells completed during 1941	1,174	61
Number of gas wells completed during 1941	153	25
Number of dry holes completed during 1941	454	243

[a] Flow pressure.

beginning of the year to an average of 3643 bbl. for 1941.

South Konawa.—In the South Konawa pool, a 1938 Hunton limestone discovery, 26 oil wells with an average initial of 371 bbl., one recompletion, and one dry hole were completed during 1941. Production for the year averaged 1970 bbl. daily.

Oklahoma City.—Development in the Oklahoma City pool, the state's greatest oil pool, continued throughout the year, and 38 oil-well completions averaged 336 bbl. per day of initial production, compared with 29 oil wells with an average of 500 bbl. initial for the preceding year. Production averaged 87,620 bbl. per day during the year against an average of 97,600 bbl. during 1940. Total production from the pool to the end of 1941 approximates 545,000,000 bbl., of which approximately 413,000,000 bbl. was produced from the Wilcox sand, which is 100 ft. thick on an average and covers an area of some 7000 acres.

Oil and Gas Development in Northern and Central Pennsylvania during 1941

By Arthur C. Simmons,* Member A.I.M.E.

The State of Pennsylvania produces approximately 60 per cent of the total production of Pennsylvania Grade oil, and naturally represents the dominant factor in the area producing that grade. The producing area comprises the states of New York, Pennsylvania, West Virginia, and a small part of Ohio. The importance of this area is too commonly neglected because it produces only 2 per cent of the total amount of crude produced in the United States. It is, of course, unimportant in its percentage of total crude production, but extremely important for its production of lubricating oil.

The lubricating fraction from a barrel of Pennsylvania Grade crude oil represents about 22 per cent of the total, whereas the lubricating fraction from the total United States production represents only about 2.5 per cent of the crude oil. The Pennsylvania Grade area produces about 6,000,000 bbl. of lubricants, which is 15 to 20 per cent of the total produced in the United States. All Pennsylvania Grade lubricants are classified as "high-grade," and with a production of 15 to 20 per cent of the total lubricants, it appears probable that the Pennsylvania Grade area accounts for 25 to 50 per cent of the high-grade lubricants produced in the United States.

Production

Bradford Field

The production figures quoted in Table 1 apply only to the part of the Bradford field that lies wholly within the state of Pennsylvania; approximately 15 per cent of the Bradford field is in Cattaraugus County, New York, and 10 per cent of the production is obtained from that sector. The Bradford-field production in 1941 was 12,729,900 bbl. as compared with a production in the year 1940 of 12,748,279 bbl., or a reduction of 18,379 bbl. The year 1941 represents the fourth successive year in which production in the Bradford field has declined. All of the production from the Bradford field is obtained by water-flooding methods and increases or decreases in production are due more to economic factors than to any physical limitations of the pool, inasmuch as additional drilling of water-intake and producing wells would increase the total production of the field. It is apparent that increased drilling of oil and water-intake wells does not take place except under stimulus of a favorable price; and while oil prices during 1941 were moderately favorable, they were not sufficient to prevent a mild decline.

Too many wells were drilled in the Bradford field in 1937, but this was compensated by subnormal drilling activities in 1938 and 1939 and a large increase in 1940. The increase in 1941 over 1940 was about 7 per cent. The effect of new drilling is becoming less pronounced on a per well basis because more properties yielding less per acre are being drilled than were drilled in former years.

Central and Southern Pennsylvania

The production in central and southern Pennsylvania amounted to a total of

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4,104,100 bbl. during 1941, which represents a decrease of 500,663 bbl. from the year 1940. The decrease in central and southern Pennsylvania amounted to about 1400 bbl. per day; approximately 500 bbl. per day of this amount is attributable to the Music Mountain pool and 900 bbl. per day to the remainder of the area.

TABLE 1.—*Oil Production, State of Pennsylvania*

	Wells Completed, Bradford Field[a]	Change	Oil Production, Bradford Field, Bbl.[b]	Change	Oil Production, Central and Southern Pennsylvania, Bbl.[c]	Change	Oil Production, State of Pennsylvania, Bbl.	Change
Total:								
1937	4,112		15,076,909		4,108,100		19,185,109	
1938	2,148	−1,964	13,417,102	−1,659,807	4,008,923	− 99,177	17,426,025	−1,758,984
1939	2,114	− 34	12,899,104	− 517,998	4,438,035	+429,112	17,337,139	− 88,886
1940	3,004	+ 890	12,748,279	− 150,825	4,604,763	+166,728	17,353,042	+ 15,903[c]
1941	3,207	+ 203	12,729,900	− 18,379	4,104,100	−500,663	16,834,000	− 519,042
Daily average:								
1937			41,300		11,255		52,555	
1938			36,759	− 4,541	10,983	− 272	47,742	− 4,813
1939			35,340	− 1,419	12,159	+ 1,176	47,499	− 243
1940			34,831	− 509	12,581	+ 422	47,412	− 87[c]
1941			34,876	+ 45	11,244	− 1,337	46,120	− 1,292

[a] Includes oil and water-intake wells and New York state part of Bradford field.
[b] Pennsylvania production only.
[c] Variance between total production and daily average occasioned by 365-day year in 1939 and 366-day year in 1940.

With the exception of the Music Mountain pool, which is being produced both by natural methods and secondary gas repressuring, and the Clarendon field in Warren County, all the remainder of Pennsylvania oil is produced either by natural wells or by air-gas repressuring. It is not practicable to subdivide the production in the various districts of Pennsylvania or to differentiate between air-gas production and natural production; however, it appears probable that the large majority of Pennsylvania production, other than Bradford, is obtained by some degree of repressuring. It is apparent that new developments in air-gas repressuring are not sufficient to overcome the natural decline encountered in the remainder of Pennsylvania, and the prevention of this decline can only be overcome with a sufficient price incentive to permit more intensive air-gas repressuring.

Music Mountain Field

The Music Mountain field was discovered in 1937 and since that time has been producing by natural methods and gas repressuring. This pool produced a peak in March 1940 of approximately 6200 bbl. per day, whereas in 1941 the yearly average was only 2865 bbl. per day. The daily average production in 1941 is shown in Table 2. This particular pool showed a continuous decline from January through December, in spite of additional drilling of "inside" locations.

TABLE 2.—*Daily Average Production, Music Mountain Field*

Month	Bbl.	Month	Bbl.
January	4,075	July	2,350
February	3,800	August	2,300
March	3,750	September	2,400
April	3,375	October	2,500
May	3,350	November	2,200
June	2,750	December	1,600

CRUDE-OIL PRICES AND STOCKS

The price of Bradford Pennsylvania Grade crude oil varied from a minimum of $2.15, which was applicable on Jan. 1, 1941, to a maximum of $2.98 on Aug. 14, 1941; this price was reduced to $2.75 on Aug. 23, 1941, by order of the Office of Price Administration. The $2.75 price prevailed for the remainder of the year and the average price realized throughout the entire calendar year was $2.56 per barrel. The over-all average represents an increase of 24¢ per barrel more than the average realized in 1940, which was $2.32. Table 3 includes all price changes throughout the year for Bradford, Allegany, Southwest Pennsylvania, West Virginia, and Ohio areas.

TABLE 3.—*Market Price Changes Pennsylvania Grade Crude*

Date	Bradford	Allegany	Southwest Pa.	West Va.	Ohio
Jan. 1	$2.15	$2.15	$1.80	$1.74	$1.70
Jan. 27	2.30	2.30	1.95	1.89	1.85
Apr. 23	2.40	2.40	2.05	1.99	1.95
May 21	2.55	2.55	2.20	2.14	2.10
June 18	2.75	2.75	2.40	2.34	2.30
Aug. 14	2.98	2.98	2.65	2.59	2.55
Aug. 23	2.75	2.75	2.40	2.34	2.30
Average	$2.565	$2.565	$2.215	$2.115	$2.115

At the beginning of 1941 the stocks of Pennsylvania Grade totaled 4,034,000 bbl. and these declined to approximately 3,260,000 bbl. by the end of the year, representing an over-all reduction of 19 per cent. In 1940 the stocks of Pennsylvania Grade crude oil reached a low of 4,010,000 bbl. as of March 31, 1940, which was the lowest point of record; consequently the storage as of the end of 1941 of 3,260,000 bbl. represents an all-time low in storage of Pennsylvania Grade crude oil. This storage of Pennsylvania oil represents a dangerous and uneconomic amount because a large portion of it is "unavailable," being included as tank bottoms and pipeline fill.

It is interesting to compare the decline in storage of Pennsylvania Grade with the decline in storage of all United States stocks, which dropped during the year about 11 per cent, whereas Pennsylvania Grade stocks declined approximately 19 per cent.

GAS DEVELOPMENTS

No new gas fields of consequence were discovered in Pennsylvania during 1941, and the existing fields declined so much that it is difficult to maintain both domestic and industrial gas service. Considerable additional drilling was done in the older fields and many unsuccessful dry holes were drilled in exploring for deep gas production.

SUMMARY

The small decline realized in production of crude oil within the state of Pennsylvania during 1941 was unavoidable, but this decline could be minimized or reversed with a price sufficient to stimulate new developments. The recoverable crude-oil reserves in Pennsylvania are comparable in years supply with the total United States reserves, but a large part of these reserves cannot be recovered at existing price levels. The over-all average price of $2.56 per barrel was more favorable than that in previous years since 1937, when the average was $2.60 per barrel.

Production of Pennsylvania Grade crude oil is relatively unimportant when compared with the crude production of the United States but it is valuable because of its yield of lubricants, which is a large percentage of the total yield of high-grade lubricants in the United States.

The methods used in the production of Pennsylvania crude oil during 1941 were similar in all respects to methods employed in previous years, inasmuch as the Bradford field in Pennsylvania and New York states and the Bolivar field in Allegany County, New York, produced almost wholly by water-flooding methods and the remainder of the area produced by both natural production and air-gas repressuring.

Oil and Gas Developments in Southwestern Pennsylvania during 1941

By John T. Galey*

The outstanding developments of the year in southwestern Pennsylvania were the establishment of the Summit Fayette County gas pool and the gas pool in Nicholson township, Fayette County, and Monongahela township, Greene County, as major producing areas, and the indication of four new shallow gas pools. Curtailment of drilling for shallow gas is expected to follow order M68 of the Office of Production Management. Gas completions were approximately 70 per cent higher, oil completions nearly 25 per cent lower, dry holes were unchanged and drilling wells as of Dec. 31, 1941, nearly 100 per cent higher than last year.

Shallow Development

Oil.—Outside Butler County, only 11 producers were drilled, with a total initial of 221 bbl. The best of these was in a portion of Gilmore township, Greene County, which ordinarily produces gas. This well flowed 77 bbl. in 11 hr., along with about one million cubic feet of gas from the Fourth (U.Dev.) sand. Washington County had a 10.20 and a 25-bbl. well in Morris township and a 20-bbl. well in South Franklin township. These were all in the Fifth Sand.

The price of oil to Jan. 27 was $1.80 per barrel, when a 15¢ increase was made. This was followed by a raise of 20¢ on Apr. 23, 15¢ on May 21, 20¢ on June 18 and 25¢ on Aug. 14. The last increase was canceled on Aug. 23 by the Office of Price Administration, which pegged southwestern Pennsylvania crude at $2.40 per barrel.

Gas.—An almost doubled initial production of natural gas is the result of the large increase in number of wells drilled. The outstanding discovery of the year was in the vicinity of Armbrust, Hempfield township, Westmoreland County, where a well drilled to what at first was considered the Bayard sand, but what is now known to be the Fifth (U.Dev.) sand, at 2100 ft. found nearly 5 million cu. ft. of gas. Since this completion 14 wells have been finished, only one of which was dry, giving a combined total open flow of approximately 15 million cu. ft. The sand is 35 to 40 ft. thick and the saturation extends through most of that thickness. Rock pressure, which is 1040 lb. per sq. in., is abnormally high. An area of only about one square mile has been proven but some of the 24 new wells drilling as of Dec. 31 will no doubt extend it considerably. This development has taken place in an area heretofore considered to have had little prospect.

There were three good wells in other parts of Westmoreland County. One well in Franklin township, which had 12 million cu. ft. of gas in the Fifth sand, was entirely surrounded by dry holes but is still producing at a high rate. In Bell township a 1.6 million cu. ft. well was found in the Speechley (U.Dev.) sand and in Washington township the same sand produced 2.7 million cu. ft. with shut-in pressure of 970 lb. at 2820 ft. This well is offset by two dry holes and one well with a capacity of only 10 M cubic feet.

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Two notable gas-well completions were made in Forward township, Allegheny County, where 2 million cu. ft. was found in the Big Injun (Miss.) and 9 million cu. ft. in the Bayard (U.Dev.) sand. Both of these were in old producing areas.

Armstrong County, which leads in the number of completions, had only two good wells, both of which were in the Fifth sand. One of these, in Kittanning township, had 1.5 million cu. ft. with 585 lb. rock pressure, while the other, in Valley township, had 1.3 million cu. ft. with 730 lb. rock pressure at 1592 ft. The last-named well gives indication of opening a new pool. Many of the wells, both here and in Indiana County, were drilled to the Bradford (U.Dev.) sand, in which only small production was found.

In Cranberry township, Butler County, where there is some oil production in the Hundred-foot (U.Dev.) sand, a well drilled to the Butler County gas sand (Miss.) had 2.875 million cu. ft., with 325 lb. rock pressure at 1180 ft. A second well, however, failed to find production.

Gas was found in 10 different sands in Fayette County. An effort made to extend the Bradford sand find of last year in Franklin township met with only slight success; one of the two wells drilled proved dry and the second had only 60 M cu. ft. The best Big Injun (Miss.) sand wells made 1.25, 1.5, 1.7, 2 and 3 million cu. ft. in Nicholson township, where the greatest part of the activity was centered. German township had a one-million-cu.-ft. well in the same sand and along the same trend of the Big Injun sand in Greene County there were drilled 1.2, 1.75, 2.1, and 13 million-cu.-ft. wells. This trend, extending over a distance of 16 miles, has developed into one of major proportions. Another large Big Injun sand well was drilled in Fayette County, Jefferson township, which was completed for 4.142 million cu. ft. In Center township there was a completion for 1.3 million cu. ft. in the Fifty-foot (U.Dev.) sand, and in Whitley township a well was completed for nearly 0.7 million cu. ft. in the Bayard sand.

The three outstanding wells in Washington County were also in the Big Injun sand. Two of these, in West Bethlehem township, produced 0.75 million cu. ft. under 720 lb. rock pressure, and in North Strabane township a well flowed slightly over 1 million, both indicating the possibility of new pools. Another well in South Franklin township produced 6.5 million cu. ft. in the same sand.

DEEP-SAND DEVELOPMENT

Deep-sand (L.Dev.) completions totaling 10 were more numerous than during any year in the short history of that activity which now records 47 Onondaga or Oriskany tests, of which three were drilled by the rotary method. This is largely the result of the development of the Summit, Fayette County, gas pool, where five new wells are commercial.

Five wildcat wells were drilled to the Oriskany and failed to find production. Two of these were in New Sewickley and Center townships, respectively, in Beaver County. They were located on seismograph highs, ran normal as to depth and found salt water. A well drilled on a very gentle surface fold in Springfield township, near the southern border of Mercer County, encountered only 2 ft. of poor Oriskany sand, but it is reported to be drilling to the Medina (L.Sil) sand. In West Franklin township, Armstrong County, a well drilled on a pronounced closure on the Kellersburg anticline was normal in every respect except for the presence of the Oriskany sand, only 1 ft. of the horizon being present. The deep test on the Laurel Hill anticline in Stewart township, Fayette County, had only a small show of gas in the Oriskany, as apparently it penetrated that formation nearly 700 ft. lower than was anticipated after it had crossed over to the downthrown side of the east flank fault. This well, completed at a depth of 8498 ft., is the deepest cable-tool hole in the state and the second deepest in the Appalachian area.

Two interesting wildcats are nearing the critical stages. One is situated on a well-defined closure of the Fayette anticline, in South Huntington township, Westmoreland County, while the other is on a gentle surface closure of the Washington anticline, Richhill township, in the northwest corner of Greene County. Each of these has encountered the Onondaga at regionally high subsea elevation.

Locations for two new deep tests have been made. One is to be drilled in Ligonier township, Westmoreland County, on a well-defined surface dome of the Laurel Hill anticline, approximately 2½ miles southwest of the Indiana Savings and Trust Co. well completed in 1937, which had nearly 700 M cu. ft. of gas accompanied by salt water in the Onondaga and a large volume of salt water in the Oriskany. The other test, in Slippery Rock township, Lawrence County, is in the abandoned Big Meadows gas pool discovered about 50 years ago. Production was derived originally from the Murraysville, or Butler County, gas sand (Miss.). Four deep tests were drilled in this area, commencing in 1933. Two of these found hard, dry sand; one had a small show of oil and gas with no salt water, and the other had nearly 70 M cu. ft. of gas accompanied by salt water in the Oriskany. Detailed surface and subsurface work projected to the Oriskany sand shows the latter well to have been drilled low on the flank of a small dome, and the new test is being drilled in a position expected to have a subsea elevation some 20 ft. higher.

TABLE 1.—*Wells Drilled for Oil and Gas in Southwestern Pennsylvania during* 1941, *Together with Initial Oil and Gas Production Developed*[a]

County	Number of Gas Wells	Initial Open Flow, M Cu. Ft.	Number of Oil Wells	Initial Production, Bbl.	Number of Dry Holes	Drilling as of Dec. 30, Wells
Allegheny	11	14,399	1	5	4	3
Armstrong	103	15,642	0	0	7	21
Beaver	1	50	0	0	2	0
Butler	7	3,000	36	75	17	5
Fayette	45	37,075	0	0	15	17
Greene	74	49,974	5	137	12	25
Indiana	11	602	0	0	11	3
Lawrence	3	150	0	0	2	0
Washington	48	15,697	5	79	11	13
Westmoreland	37	34,030	0	0	2	30
Total	340	173,619	47	296	83	117

[a] Includes deepening operations.

SUMMIT POOL

A 2-mile southwest extension of production, the discovery of a new productive horizon and the proving of faulting of great magnitude, marked developments in the Summit pool, where eight gas wells and one dry hole had previously been drilled. Production here has been in the Onondaga chert and in the Oriskany sand. The four gas wells completed averaged nearly 3 million cu. ft. each and the highest on structure had 5.7 million cu. ft. in the Onondaga without reaching the Oriskany. Two miles southwest of the proven area a test is drilling in the Onondaga, which, while running nearly 800 ft. lower than the top of the structure, has already found 2.5 million cu. ft. of gas.

Another well drilled in the proven area, which had gas in the Onondaga and a small volume in the Oriskany, found production in the Helderberg (L.Dev.) chert. This is the first production from the latter horizon in southwestern Pennsylvania. However, two wells previously

TABLE 2.—*Deep Drilling in Southwestern Pennsylvania during* 1941 (*Including Deepening Operations*)

County	Township	Name	Elevation, Ft.	Top Tully, Ft.	Top Onondaga, Ft.	Top Oriskany, Ft.	Total Depth, Ft.	Remarks
Beaver	New Sewickley	Pflug No. 1	1,153		5,276[2]	5,438	5,449	3 M cu. ft. gas 5440; SW. 5441, SW.
Beaver	Center	Koehle hrs. No. 1	1,066		5,145[2]	5,312	5,345	SW. 5319-5330
Armstrong	West Franklin	Beidenbach No. 1	1,174	5,416	5,773[2] 5,791[2]	5,907	6,000	Only Oriskany sand horizon present. Temp. 5965 ft., 146.2°F.[1]
Fayette	Georges	Barton No. 1	2,317	6,442	7,142[2] 7,158[3,4]			2,500 M cu. ft. in Onondaga; drilling 3250 lb. R.P.
Fayette	North Union	Piedmont No. 1	2,176	6,060	6,657[2] 6,692[3,4]	7,035[4]	7,350	Drilled deeper no add. gas
Fayette	North Union	Sorg No. 2	2,511	6,351	6,984[2] 7,068[3,4]	7,282[4]	7,434	2,500 M cu. ft. total
Fayette	South Union	Heyn No. 3	2,316	5,845	6,305[2] 6,395[3,4]	6,579[4]	6,792	2,125 M cu. ft. gas total
Fayette	South Union	Heyn No. 4	2,531	6,005	6,480[2] 6,505[3,4]		6,578	5,690 M cu. ft. gas net through Onondaga R.P. 2095 lb.
Fayette	South Union	Piedmont No. 3	2,405	6,047	6,742[2] 6,797[3,4]	7,083[4]	7,272	2,800 M cu. ft. gas total including gas in Helderberg below Oriskany
Fayette	South Union	Piedmont No. 4	2,491	6,756				Drilling 7803 in fault
Fayette	South Union	Piedmont No. 5	2,460	5,977	6,540[2] 6,576[3,4]	6,740[4]	7,080	1,011 M cu. ft. gas total
Fayette	South Union	Carothers No. 1	2,567					Drilling 5475 in fault.
Fayette	Stewart	Neel No. 1	2,566	7,790	8,050[3]	8,304[4]	8,498	Show gas 8250 downthrown side of fault
Fayette	Wharton	Kirby No. 1	2,690					Cementing 6360 in fault
Greene	Richhill	Workman No. 1	1,246		6,776[2]			
Lawrence	Slippery Rock	Miller and Myers No. 1	1,207					
Mercer	Springfield	Collins No. 1	1,289	4,276[2]	4,424			Fishing 4570. Only Oriskany horizon present
Westmoreland	Ligonier	Beck No. 1	2,784					Building road
Westmoreland	South Huntington	Jacobs Creek No. 1	964	6,720	7,317[2] 7,348[3]			Fishing in Onondaga.

[1] Obtained by seven maximum thermometers suspended in sand pumpings between runs at 5965 feet.
[2] Onondaga lime.
[3] Onondaga chert.
[4] Pay.

drilled into the Helderberg in this vicinity found no gas.

The three remaining drilling wells have passed through faults and are encountering difficulty in drilling. One of these, which has crossed over to the downthrown side of the west flank fault, is running nearly 1000 ft. lower than the top of the structure and has been drilling for some distance in apparently steeply dipping Marcellus shale.

GEOLOGY

The most important development from a geological standpoint during the year, aside from the proving of faulting of great magnitude at Summit, Fayette County, mentioned above, is the extension of the Oriskany "no sand" area to the west and south by wells in West Franklin township, Armstrong County, and Springfield township, Mercer County, respectively. This extension further delimits the territory in which stratigraphic traps may be found.

Insofar as shallow development is concerned, a more careful study than has ever before been made of sand condition has yielded results in several widely separated areas. The large Bayard sand well in Forward township, Allegheny County, is one example of what can be done by this means.

SEISMOGRAPH WORK

The seismograph is credited with the 2-mile southwest extension of the Summit-Fayette County gas pool. Two wildcats drilled on seismograph highs found salt water in the Oriskany and favorable surface structure was lacking.

One of the major oil companies has shot over a strip of territory in the southwestern part of Pennsylvania approximately 50 miles wide and extending almost as far north as the glaciated area. Their findings have not resulted in any lease play, possibly for the reason that much of the acreage worked is already under lease or production.

DRILLING TECHNOLOGY

Highly explosive gas pockets in the Marcellus shale, almost entirely in the western portion of the area, create a severe hazard in deep (L.Dev.) drilling. Ordinarily, this hazard is overcome by the use of a column of brine carried in the hole as drilling fluid. In a test in Center township, Beaver County, where this technique was not employed, five strings of tools were lost and finally it became necessary to skid the rig after over 5000 ft. of hole was drilled. In Rich Hill township, Greene County, difficulty was encountered in drilling the gas-pocket zone even though salt water was employed, but this was occasioned by the carrying of too short a column of brine in the hole when the gas pockets were struck. This is the deepest well in which a column of brine has been carried to date, and it was found impracticable to bail the muddy brine from the hole and replace it every 24 hr., particularly in view of the 4000 ft. of open hole, which made necessary the dumping of the brine with the bailer. Satisfactory results were obtained, however, by removing only 10 bailers of muddy brine and replacing them with the same quantity of fresh brine each 24 hr., which is over and above the one bailer exchanged at the end of each run. Perhaps the optimum results will be obtained with the method when pipe is carried along with the hole, thus requiring a smaller volume of brine to obtain the maximum hydrostatic head, and permitting the brine to be poured from the top rather than lowered by the bailer.

PIPE-LINE CONSTRUCTION

A new gas line is projected from the Louisiana gas fields to West Virginia. Much of the gas transported over this line would come through existing facilities into southwestern Pennsylvania. The volume it is considered possible for the line to carry would just about equal one year's depletion of gas reserves in this area. Thus, no decline in drilling activity is foreseen as a result of the line, particularly in view of the fact that new production developed during the year does not normally balance depletion. In addition, industrial demand for gas is advancing so rapidly because of the war effort that there is already such a shortage that industrial gas is rationed during periods of peak loads. However, it seems possible that sufficient new gas reserves to prevent any shortage here can be developed by intelligently prospecting the deeper, hitherto little explored horizons, including the Oriskany, on already known structures.

Oil and Gas in the Rocky Mountain District in 1941

By C. E. Shoenfelt,* Member A.I.M.E.

Table 1.—*Oil and Gas Production in the Rocky Mountain District*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
	Colorado					
1	Berthoud, *Larimer*	1927	510	320	60,332	3,090
2	Boulder, *Boulder*	1902	400		654,677	4,893
3	Florence, *Fremont*	1862	9,000		13,732,757	53,431
4	Ft. Collins, *Larimer*	1923	400		2,232,047	45,235
5	Garcia, *Las Animas*	1927		640		
6	Greasewood, *Weld*	1930	200		470,794	7,104
7	Hamilton, *Moffat*	1924	400		5,797,056	115,529
8	Hiawatha, *Moffat*	1928	640	3,180	338,804	191,572
9	Iles, *Moffat*	1924	600		9,073,849	555,946
10	Model, *Las Animas*	1929		4,380		
11	Powder Wash, *Moffat*	1936			40,154	40,154
12	Price, *Archuleta*	1934	200		1,189,431	330,017
13	Rangely, *Rio Blanco*	1919	320		973,212	224,258
14	Thornburg, *Rio Blanco*	1925		350		
15	Tow Creek, *Routt*	1924	200		1,737,648	49,291
16	Walden, *Jackson*	1927	320		85,336	0[1]
17	Wellington, *Larimer*	1924	1,000		4,921,146	71,532
18	Wilson Creek, *Rio Blanco*	1938	640		871,270	451,819
	Montana					
19	Border, *Toole*	1930	450		1,085,432	25,299
20	Bowdoin-Saco, *Phillips*	1916		100,000		
21	Bowes, *Blaine*	1926		3,000		
22	Boxelder, *Hill*	1931		900		
23	Cat Creek	1920			15,007,882	167,623
24	First sand		600			
25	Second sand		240			
26	Cedar Creek, *Dawson, Fallon and Wibaux*	1913				
27	First sand			110,000		
28	Second sand					
29	Madison lime	1936	80		27,287	9,699
30	Cut Bank, *Glacier*	1932	38,000	55,000	26,018,008	5,015,862
31	Dry Creek, *Carbon*	1930				
32	Frontier			1,760	1,851,877	166,713
33	Cloverly					
34	Elk Basin, *Carbon*	1916	140		1,021,438	17,654
35	Hardin, *Big Horn*			2,000		
36	Haystack Butte					
37	Kevin-Sunburst, *Toole*	1922	60,000		39,633,741	1,759,624
38	Lake Basin, *Stillwater*	1924	300	1,500	462,773	18,414
39	Pondera, *Pondera and Teton*	1927	1,600		5,945,164	281,747
40	Sweetgrass Hills, *Liberty and Toole*	1929	500	8,000	108,375	7,413
	Utah					
41	Ashley Valley, *Uinta*[7]	1926		240		
42	Cisco, *Grand*	1925		2,000		
43	Clay Basin, *Daggett*	1928		2,800		
44	Farnham, *Carbon*	1924		600		
45	San Juan, *San Juan*	1910	160		14,*xxx*	50
46	Virgin, *Washington*	1908	450		181,625	

[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Wells produce large quantities of CO_2 with the oil—shut in.

[7] Field abandoned 1941.

Manuscript received at the office of the Institute May 13 and May 18, 1942.

* Geologist, Petroleum Information, Denver, Colorado.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	
				During 1941		End of 1941			Number of Wells					
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
							COLORADO							
1	727.3	50.3	6			1	1	1		1	600	75	38.5	0.1
2			57	2	1	1	9			9			38.6	0.2
3			1,209	1			106			106			31.0	0.1
4			16				8			8			37.0	0.1
5	8,500	70.2	16					6			12	[3]		
6			8				1			1			42.0	0.1
7			25	2			11			11			41.0	0.1
8	26,241.5	2,301.5	18	4			5	2	5		850	y[4]	36.9	0.1
9			54				30			30			37.0	0.1
10	645[2]	0	8			5					12	Shut in		
11	477.3	477.3	7	2	1		2	5	2		685	685	38.2	0.1
12			20				9			9			40.0	0.1
13			111	22	12		17			17			43.0	0.1
14	444.1	101.0	4					3			725	650		
15			17				9			9			35.0	0.1
16			5			5							50.0	0.1
17			32				11			11			37.4	0.1
18			8	4			6		6				46.0	0.1
							MONTANA							
19			30	0	8		9			9			34	
20														
21														
22														
23			331		1		118			118				
24													49	
25													49	
26														
27														
28														
29			3		1	1	1		1				19	
30			794	119	12		637	81		637			41	
31														
32			16				7		7				51	
33														
34			34	1		1	22			22			43	
35														
36														
37			2,638	58	19		1,048	197		1,048			34	
38			40				2			2			44.1	
39			187				153			153			37	
40			37	3	2		9	20		9			36	
							UTAH							
41	22,015	15	5		5			0			580	100		
42	3,128	0[8]	17								750	325[10]		
43	143,612.5	4,689.5	8					7			2,250	y		
44	8,971.9	101.5[9]	2					1			750	280		
45			116				1						39	
46			132				18						34	

[2] Contains 7.9 per cent helium, balance nitrogen and CO_2.
[3] Operating under vacuum.
[4] Gas is produced from sand lenses. Initial pressures range from 661 to 1315 lb. per sq. in.
[8] Field abandoned 1937.
[9] Carbon dioxide gas.
[10] Pressure at time of abandonment.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
	COLORADO									
1	Hygiene	CreU	S	20	2,920	2,940	20	A	Lakota (CreL)	4,031
2	Pierre	CreU	H		2,000			MF		
3	Pierre	CreU	H		2,200			TS	Fountain (Pen)	1,875
4	Muddy-Dakota	CreU	S	12	4,535	4,560	25	A	Sundance (Jur)	5,206
	Sundance	Jur	S	16	5,063	5,202	139			
5	Benton	CreU	H		1,600			D	Fountain (Pen)	2,500
6	Muddy	CreU	S	9	6,645	6,680	35	A	Morrison (Jur)	7,040
7	Dakota	CreU	S	18[5]	3,860	3,880	20	D	Sundance (Jur)	4,490
	Sundance	Jur	S	14						
8	Wasatch	Eoc	S	*y*	Sand lenses			D	Mesa Verde (CreU)	7,577
9	Sundance	Jur	S	9	3,295	3,315	20	D	Sundance (Jur)	3,447
10	Santa Rosa (?)	Tri	S	19	960	1,004	50	D	Fountain (Pen)	2,010
11	Wasatch	Eoc	S	Por	Sand lenses			D	Wasatch (Eoc)	5,878
12	Dakota	CreU	S	*y*	1,120	1,140	20	A	Dakota (?)	1,350(?)
13	Mancos	CreU	H		600			A	Pennsylvanian	7,173
14	Dakota	CreU	S	15	2,200	2,230	30	D	Sundance (Jur)	3,110
15	Mancos	CreU	H		2,600			A	Gneiss[6]	5,310
16	Muddy-Dakota	CreU	S	14	5,110	5,215	90	AF	Morrison (Jur)	5,258
17	Muddy-Dakota	CreU	S	12	4,480	4,500	20	A	Sundance (Jur)	4,992
18	Morrison	Jur	S	*y*	6,550	6,675	125	D	Sundance (Jur)	6,981
	MONTANA									
19	Vanalta	CreL	S, SH	14	2,470	2,500	15	MC		
20	Colorado	CreU	SH		750	720	50	D		
21	Eagle	CreU	S	15	975	1,045	100	D		
22	Eagle	CreU	S	17	1,200	1,272	100	A		
23										
24	First Cat Creek	CreU	S	15	1,200	1,245	50	AF		
25	Second Cat Creek	CreL	S	15	1,400	1,440	40	AF		
26										
27	Judith River	CreU	S	15	830	900	70	A		
28	Eagle	CreU	SH	*y*	1,460		60	A		
29	Madison	Mis	L	*y*	6,750	6,800	50	A		
30	Cut Bank	Jur	S	14	2,800	2,835	30	MC		
31										
32	Frontier	CreU	S	18	4,400	4,450	50	AF		
33	Cloverly	CreL	S	*y*	5,500	5,525	25	AF		
34	Frontier	CreU	S	15	1,000	1,200	40	AF		
35	Frontier	CreU	S	*y*	700	730	20	MF(?)		
36										
37	Ellis-Madison Contact	Jur-Mis	L	*y*	1,450	1,470	10	D		
38	Eagle, Frontier, Dakota	CreU, L	S	*y*	1,200	1,320	100	D		
39	Madison	Mis	L	*y*	1,975	1,990	10	T		
40	Upper Ellis	Jur	S	*y*	1,400	1,420	20	D		
	UTAH									
41	Morrison	Jur	S	*y*	1,665	1,675	10	AF		
42	Dakota	CreU	S	*y*	2,056	2,174	15	D		
	Morrison	Jur	S							
43	Dakota	CreU	S	18	5,700	5,800	40	D		
44	Coconino	Per	S	*y*	3,093	3,114	21	AF		
45	Goodridge	Pen	S	*y*	194	200	6	S		
46	Kaibab-Moenkopi contact or Upper Kaibab	Tri	L	*y*	663[11]	665	2	MC		

[5] Figures from recovery indicate 20 per cent.

[6] Oldest sedimentary formation tested Thaynes (Triassic).

[11] 515 to 815 ft., depending on position on monoclinal structure.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
	Wyoming					
47	Alkali Butte, *Fremont*	1928	40	300	5,670	0
48	Allen Lake, *Carbon*	1933		200		
49	Ant Hills, *Niobrara*	1928	40			
50	Badger Basin, *Park*	1931	300		427,964	57,412
51	Baxter Basin (South), *Sweetwater*					
52	Frontier	1922		7,467		
53	Dakota	1922		4,310		
54	Baxter Basin (North), *Sweetwater*					
55	Dakota	1926		1,280		
56	Sundance	1928		2,280		
57	Beaver Creek, *Fremont*	1937		640		
58	Big Muddy, *Converse*	1915				
59	Shannon	1916		2,000	27,016,787	420,873
60	Wall Creek	1916				
61	Dakota	1922				
62	Big Sand Draw, *Fremont*					
63	Wall Creek	1917		1,200		
64	Lakota	1930		300		
65	Billy Creek, *Johnson*	1921		1,200		
66	Black Mountain, *Hot Springs*	1925	300	300	268,381	32,727
67	Bolton Creek, *Natrona*	1920				
68	Sundance	1920	50		27,102	0
69	Embar	1920	50			
70	Boone Dome, *Natrona*	1920		300		
71	Bunker Hill, *Carbon*	1936		480		
72	Byron Dome, *Big Horn*	1906				
73	Frontier	1922		500	5,825,510	1,091,969
74	Sundance	1929	40			
75	Embar-Tensleep	1932	2,950			
76	Cole Creek, *Natrona*	1937	900		502,245	296,932
77	Dallas Derby, *Fremont*	1883	350		3,137,238	197,596
78	Dewey Dome, *Weston*	1938	40		21,186	0
79	Dutton Creek, *Carbon*					
80	Shannon	1926		800	287,746	20,302
81	Muddy	1926	150			
82	East Allen Lake, *Carbon*	1936		410		
83	East Lance Creek, *Niobrara*	1918	400	150		
84	Eight Mile Lake, *Carbon*	1923		250		
85	Elk Basin, *Park*	1915				
86	Frontier		580	1,200	11,399,049	219,795
87	Dakota					
88	Enos Creek, *Hot Springs*	1923		Field abandoned		
89	Ferris, *Carbon*	1918	200	200	545,020	63,334
90	Ferris (West), *East Mahoney, Carbon*	1940				
91	Fourbear, *Park*	1928	500			
92	Frannie, *Park*	1928				
93	Tensleep		500		5,601,330	1,099 766
94	Garland, *Big Horn, Park*	1930				
95	Frontier		40	1,000	4,701,817	562,766
96	Dakota			1,200		
97	Embar-Tensleep		160	1,650		
98	Madison		2,000	500		
99	Golden Eagle, *Hot Springs*				Shut in	
100	Gooseberry, *Park*	1936	500			
101	Grass Creek, *Hot Springs*	1914				
102	Frontier		1,400		29,685,143	1,166,941
103	Embar-Tensleep		2,000			
104	Greybull, *Big Horn*	1907	640		346,730	0
105	Hamilton, *Hot Springs*	1913	2,000		5,556,433	316,528
106	Hidden Dome, *Washakie*	1933	50	640	338,590	29,976
107	Iron Creek, *Natrona*	1922	80	80	24,324	5,403
108	La Barge, *Lincoln, Sublette*	1923	950		7,284,669	727,553
109	Lake Creek, *Hot Springs*	1925	100			

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	
				During 1941		End of 1941			Number of Wells					
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil^c	Producing Gas^c	Flowing	Artificial Lift	Initial	Avg. at End of 1941	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
WYOMING														
47			3	0	0	3	0	0	0	0			37	
48														
49			3	0	0		Abandoned						35	
50			5				4		4				48	
51														
52														
53														
54														
55														
56														
57			1			1	Shut in							
58			174	0	0	0	135			135			33.5	
59														
60														
61														
62														
63														
64														
65														
66			6	0	0	0	6			6			19	
67														
68			14	0	0		Abandoned						22	
69														
70														
71														
72														
73			22	0	0		17			17			20	
74														
75														
76			16	5			14			14			32.7	
77			72	0	0		42			42			Dallas 23.2 Derby 22.3	
78			5	0	0		1			1			31	
79														
80			8	0	0		3	5		3			33.6	
81														
82														
83														
84														
85														
86			154	1	0		144	5		144			43	
87														
88														
89			27	1	0		12		2	10			36.3	
90													42.0	
91			1			1							15	
92														
93			28	8	0		19			19			27.7	
94														
95														
96			86	0	0		16	10		16			22	
97														
98														
99														
100			1			1								
101														
102			331	0	0		330			330			43	
103													22	
104			14	0	0	3	3						44.3	
105			36	0	0		33			33			Embar 25.6 Tensleep 16.7	
106			30	0	0		15			15			40	
107			5	0	0		1			1			32	
108			164	15	4		137			137			32	
109			3	0	0	1							26	

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
	WYOMING									
47	Morrison	Jur	S	Por	4,570	4,600	30	A		
48	Sundance	Jur	S	Por	2,100	2,175	40	A		
49	Dakota	CreU	S	Por	3,951	3,957	6	A		
50	Frontier	CreU	S	Por	8,250	8,500	49	A		
51										
52	Frontier	CreU	S	Por	2,200	2,400	16	AF		
53	Dakota	CreU	S	Por	3,000	3,500	50	AF		
54										
55	Dakota	CreU	S	Por	2,950	3,100	20	AF		
56	Sundance	Jur	S	Por	3,350	3,400	15	AF		
57	Lakota	CreL	S	Por	8,244	8,288	44	A		
58										
59	Shannon	CreU	S	Por	1,200	1,250	65	A		
60	Wall Creek	CreU	S	Por	3,260	3,400	100	A		
61	Dakota	CreU	S	Por	4,600	4,700	15	A		
62	Wall Creek	CreU	S	Por	2,300	2,800	150	A		
63	Lakota	CreL	S	Por	4,300	4,350	40	A		
64										
65	Wall Creek	CreU	SH	Por	3,200	3,250	30	A		
66	Embar-Tensleep	Per-Pen	LS		2,900	3,350	135	A		
67	Sundance	Jur	S	Por	1,015	1,120	10	AF		
68	Embar	Per	L	Cav	2,025	2,050	15	AF		
69										
70	Shannon	CreU	S	Por	2,150	2,200	70	A		
71	Shannon	CreU	S	Por	1,224	1,480	250	A		
72										
73	Frontier	CreU	S	Por	2,400	2,500	30	A		
74	Sundance	Jur	S	Por	4,205	4,209	4	A		
75	Embar-Tensleep	Pen, Per	LS	Cav Por	5,300	5,700	130	A		
76	Shannon	CreU	S	Por	4,550	4,650	100	A		
77	Embar-Tensleep	Per Pen	LS	Cav, Por	700	1,200	150	A		
78	Leo Zone, Minnelusa	Pen	S	Por	2,294	2,349	40	A		
79	Shannon	CreU	S	Por	1,600	1,700	40	A		
80	Muddy	CreU	S	Por	4,850	4,900	30	A		
81										
82	Sundance	Jur	S	Por	2,000	2,088	48	A		
83	Dakota	CreU	S	Por	3,808	4,008	95	A		
84	Dakota	CreU	S	Por	3,400	3,500	50	A		
85										
86	Frontier	CreU	S	Por	1,000	1,200	40	AF		
87	Dakota	CreU	S	Por	2,400	2,500	55	AF		
88	Frontier	CreU	S	Por	2,600	2,850	40	A		
89	Mowry-Dakota	CreU	S	Por	1,600	1,650	25	A		
90	Tensleep	Pen	S	Por	4,272	4,293	21	A		
91	Tensleep	Pen	S	Por	3,270	3,350	60	A		
92										
93	Tensleep	Pen	S	Por	2,770	3,530	100	AF		
94										
95	Frontier	CreU	S	Por	700	900	35	AF		
96	Dakota	CreU	S	Por	1,500	1,600	50	AF		
97	Embar-Tensleep	Per Pen	LS	Cav Por	3,000	4,275	100	A		
98	Madison	Mis	L	Por Cav	3,600	4,726	300	A		
99	Mesaverde	CreU	S	Por	2,250	3,000	50	A		
100	Embar-Tensleep	Per Pen	LS	Cav Por	5,669	6,049	50	A		
101										
102	Frontier	CreU	S	Por	800	1,200	250	A		
103	Embar-Tensleep	Per Pen	LS	Cav Por	3,600	4,000	200	A		
104	Greybull	CreU	S	Por	1,000	1,050	20	AF		
105	Embar-Tensleep	Per Pen	LS	Cav Por	2,700	3,332	130	A		
106	Frontier	CreU	S	Por	1,200	1,600	15	A		
107	Dakota	CreU	S	Por	650	820	25	A		
108	Wasatch	Eoc	S	Por	650	1,000	150	AF		
109	Embar	Per	L	Cav	3,730	3,760	30	A		

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas^{b}	To End of 1941	During 1941
110	Lance Creek, *Niobrara*	1918				
111	Dakota		1,000	3,50	41,265,770	9,181,498
112	Sundance		1,700			
113	Minnelusa		15,000			
114	Lander (Hudson), *Fremont*	1914	340		2,220,576	99,121
115	Little Buffalo Basin, *Park*	1914		4,800		
116	Little Grass Creek, *Hot Springs*			300		
117	Little Polecat, *Park*	1918		500		
118	Lost Soldier, *Sweetwater*	1915				
119	Frontier		160		22,830,792	2,213,226
120	Dakota-Lakota		450			
121	Sundance		160			
122	Tensleep		160			
123	Mahoney Dome, *Carbon*	1930				
124	Dakota			1,400	771,193	476,129
125	Sundance			1,660		
126	Tensleep		250			
127	Maverick Springs, *Fremont*	1916	1,400		502,998	490,662
128	Medicine Bow, *Carbon*	1935	800	320	3,795,068	250,388
129	Midway, *Natrona*	1930	200		175,886	0
130	Mule Creek (East), *Niobrara*	1919			1,318,078	114,838
131	Mule Creek (West), *Niobrara*					
132	Muskrat, *Fremont*			500		
133	Notches, *Natrona*	1923	400		167,054	0
134	Oil Springs, *Carbon*	1938		160		
135	Oregon Basin, *Park*	1927				
136	Dakota			1,300	16,377,193	
137	Embar-Tensleep		10,000			
138	Osage, *Weston*	1920	10.000		4,804,398	
139	Pilot Butte, *Fremont*	1916	250	400	566,752	2,480
140	Quealy, *Albany*	1934	320		1,177,974	159,700
141	Rex Lake, *Albany*	1923	200		248,300	20,101
142	Rock Creek, *Carbon*	1918				
143	Dakota		1,300		20,773,375	960,543
144	Sundance		500			
145	Salt Creek, *Natrona*	1908				
146	1st Wall Creek		4,350		298,649,755	5,086,040
147	2nd Wall Creek		21,450			
148	Lakota		2,030			
149	Sundance		660			
150	Tensleep		640			
151	Shannon, *Natrona*	1889	200		55,441	0
152	Shoshone, *Park*	1929	540		63,119	
153	Simpson Ridge, *Carbon*	1924			162,485	0
154	South Casper Creek and Poison Spider, *Natrona*	1920	240		3,720,215	161,934
155	Spindle Top, *Natrona*	1928	80		22,507	0
156	Spring Valley, *Vinta*	1903	400		101,593	0
157	Teapot (Outside Naval Reserve), *Natrona*	1927				
158	Wall Creek				110,741	5,140
159	Shale					
160	Torchlight, *Big Horn*	1915	600		254,709	0
161	Warm Springs, *Hot Springs*	1917	160		390,884	23,109
162	Waugh Dome, *Hot Springs*	1935	100		210,069	
163	Wertz, *Carbon*	1921				
164	Frontier			100	3,958,570	1,712,958
165	Dakota			500		
166	Lakota			500		
167	Sundance			200		
168	Tensleep		600			

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	
				During 1941		End of 1941			Number of Wells					
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flow-ing	Artificial Lift	Initial	Avg. at End of 1941	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
110													43.6	
111														
112			308	25	2	0	187			187				
113														
114			36	0	0		17			11			23.3	
115														
116														
117														
118														
119														
120			142	8	1		78			78			Light 32	
121													Heavy 28.8	
122														
123														
124														
125			21	3			6			6			34.2	
126														
127			38	6			33			33			22	
128			14				10	2	10				56.9	
129			3			2				2			32.5	
130			84				42			42			32	
131														
132														
133			5			2				2			16	
134			2					2						
135														
136			58	8			54			54			21.6	
137														
138			538	10	5		280			280			41.6	
139			17			2	5			5			42	
140			19				17			17			32.8	
141			4				3			3			35	
142														
143			78	4	1		58						37	
144													36	
145														
146													36	
147													38	
148			2,004	5	1		1,902			1,902			35	
149													35	
150													24	
151			18	Field abandoned										
152			3				1			1			21.1	
153			13			9	Shut in						20.4	
154			x	2			18			18			Sundance 21 Tensleep 15.3	
155			6	0	0	4							21	
156			30	0	0	2							22	
157														
158			2	0	0		2			2			48.3	
159													35.2	
160			30	0	0	x	0						45.6	
161			46	0	0		19			19			21	
162			2	Field abandoned									27.2	
163														
164														
165														
166			27	10		0	13		13					
167														
168														

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
110	Dakota	CreU	S	Por	2,820	3,665	65	A		
111	Sundance	Jur	S	Por	3,500	4,100	65	A		
112	Leo Zone-Minnelusa	Pen	S	Por	4,900	5,630	60	A		
113										
114	Embar-Tensleep	Per Pen	LS	Cav Por	1,300	2,750	185	A		
115	Frontier	CreU	S	Por	1,200	1,500	100	A		
116	Frontier	CreU	S	Por	2,665	2,901		A		
117	Frontier	CreU	S	Por	3,900	4,100	15	A		
118										
119	Frontier	CreU	S	Por	175	900	200	AF		
120	Dakota-Lakota	Cre	S	Por	1,375	2,100	80	AF		
121	Sundance	Jur	S	Por	1,875	2,100	300	AF		
122	Tensleep	Pen	S	Por	3,900	4,097	50	AF		
123										
124	Dakota	CreU	S	Por	2,170	2,300	30	A		
125	Sundance	Jur	S	Por	2,600	2,760	110	A		
126	Tensleep	Pen	S	Por	4,600	4,760	160	A		
127	Embar	Per	L	Cav	1,450	1,700	50	A		
128	Sundance	Jur	S	Por	5,200	5,430	140	A		
129	Frontier-Muddy	CreU	S	Por	5,200	5,250	60	A		
130	Lakota	CreL	S	Por	1,500	1,550	25			
	Minnelusa	Pen	S	Por	3,170	3,180	10	A		
131	Dakota-Lakota	Cre	S	Por	170	350	30	A		
	Minnelusa	Pen	H	Fis	2,800	2,830	10			
132	Frontier	CreU	S	Por	4,270	4,340	150	AF		
	Dakota	CreU	S	Por	5,306	5,320	60	AF		
133	Tensleep	Pen	S	Por	2,800	2,850	40	A		
134	Sundance	Jur	S	Por	2,225	2,353	90	A		
135										
136	Dakota	CreU	S	Por	1,500	1,550	45	AF		
137	Embar-Tensleep	Per Pen	LS	Cav Por	3,500	3,900	150	AF		
138	Newcastle (Muddy)	CreU	S	Por	220	2,154	10	ML		
139	Niobrara	CreU	H	Fis	800	1,000	15	A		
140	Muddy-Dakota	CreU	S	Por	3,260	3,320	60	A		
141	Dakota	CreU	S	Por	3,800	3,900	50	A		
142										
143	Dakota	CreU	S	Por	2,600	3,300	110	A		
144	Sundance	Jur	S	Por	3,150	3,250	100	A		
145										
146	1st Wall Creek	CreU	S	Por	1,000	1,100	100	AF		
147	2nd Wall Creek	CreU	S	Por	1,535	2,575	65	AF		
148	Lakota	CreL	S	Por	2,300	2,350	20	AF		
149	Sundance	Jur	S	Por	2,750	2,875	70	AF		
150	Tensleep	Pen	S	Por	3,970	4,180	190	AF		
151	Shannon	CreU	S	Por	800	900	75	MUP		
152	Embar	Per	L	Cav	4,300	5,000	24	A		
153	Quealy	CreU	S	Por	625	675	40	A		
154	Sundance	Jur	S	Por	1,400	1,425	35	A		
	Tensleep	Pen	S	Por	2,600	2,700	150	A		
155	Sundance	Jur	S	Por	1,100	1,125	25	A		
156	Aspen	CreU	H	Fis	400	900	x	MC		
157										
158	Wall Creek	CreU	S	Por	2,900	2,950	40	AF		
159	Shale	CreU	H	Fis	1,200	1,600	x	AF		
160	Mowry	CreU	SH	Por	400	600	50	A		
161	Embar	Per	L	Cav	700	800	50	A		
162	Embar	Per	L	Cav	3,775	3,807	35	A		
163										
164	Frontier	CreU	S	Por	2,210	2,260	50	A		
165	Dakota	CreU	S	Por	3,500	3,550	50	A		
166	Lakota	CreL	S	Por	3,700	3,750	40	A		
167	Sundance	Jur	S	Por	4,100	4,120	20	A		
168	Tensleep	Pen	S	Por	5,859	6,318	300	A		

Oil and Gas Developments in Tennessee in 1941

By Kendall E. Born*

Production of crude oil in Tennessee during 1941 was slightly more than 15,000 bbl., about the same as in the preceding year. Two thirds of the total was from the Mississippi limestone pools in Scott and Morgan Counties. About a dozen small scattered wells in Clay, Pickett, and Fentress Counties, pumped irregularly, produced approximately 5000 bbl. Natural gas was marketed from wells in Morgan and Fentress Counties for consumption in the Sunbright and Jamestown areas, respectively. The production by counties is shown in Table 1.

Table 1.—*Oil Production in Tennessee in 1941*

County	Number of Wells Pumped	Production, Bbl.	
		1940	1941
Scott	4	3,596	4,528
Morgan	19	5,751	5,670
Fentress	2	1,5*xx*	1,8*xx*
Pickett	2	1,2*xx*	5*xx*
Clay	10	3,*xxx*	2,850

Developments

Drilling activities in the state fell to the lowest stage since 1933. Twenty-seven wells were spudded in during 1941, of which six were drilling or only temporarily suspended on Dec. 31, 1941. Of the 22 completions, four were gas wells of undetermined quantity, but are classed as commercial, and 17 were dry or near-dry holes. One well encountered oil, but it has not been tested. The total footage drilled during the year was 29,916 ft.; the average depth of wells was 1359 ft. The more important wildcats are listed in Table 2; the distribution of tests according to physiographic divisions is given in Table 3.

East Tennessee.—One well was drilled to 3480 ft. in northwestern Anderson County, in the highly disturbed Appalachian area, a region long considered the most unfavorable in the state for the accumulation of oil and gas. Another test is now drilling below 2000 ft. in this general area.

Cumberland Plateau.—There were two completions in the Cumberland Plateau area. One test, drilled in northwestern Scott County in an area of former Mississippi limestone production,[1] encountered a considerable amount of free oil at 850 ft., about the same horizon as in the old abandoned wells. No pumping tests have been made to date. A well at Oneida, Scott County, found gas at 1579 ft. in a sandy limestone of lower Mississippian age. The volume was reported doubled by a shot, although no open-flow measurement is available.

Eastern Highland Rim.—Six completions on the eastern Highland Rim resulted in two small gas wells in Fentress County, which will be used to augment the supply for Jamestown. The producing horizons are shaly limestones of Ordovician (Trenton) age. Two wells in this area tested the upper part of the Knox dolomite group, one of which encountered some free oil in a sandy dolomite at 1670 to 1681 ft. A test high on a well-defined structure in Clay County found a considerable amount

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* Tennessee Division of Geology, Nashville, Tennessee.

[1] L. C. Glenn: Tennessee Geol. Survey, Resources. (1915) V, 174–194.

of heavy, wet gas in the Stones River limestones, which produce oil elsewhere in the county. The flanks of this structure will be drilled in 1942.

Western Valley.—Three wells in the Western Valley of Tennessee River were drilled into the Knox dolomite without finding encouraging shows of oil or gas.

TABLE 2.—*Important Wildcat Tests Drilled in Tennessee during* 1941

County	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
Fentress	8 mi. W. SW. of Jamestown	1,884	M. Mis	Knox (Ꞓ-Ord)	Travis Smith et al.	Oil show in Knox 1760–1770 ft.
Fentress	3 mi. S. SW. of Jamestown	1,219	M. Mis	Trenton (Ord)	Joe Young	Gas well in Trenton at 825 ft.
Hardin	5 mi. N. of Cerro Gordo	1,500	Trenton (Ord)	Knox (Ꞓ-Ord)	W. L. Dobie et al.	Well-defined surface structure
Lauderdale	5 mi. SW. of Halls	3,289	Recent	Knox? (Ꞓ-Ord)	Pure Oil Co.	Seismograph structure
Pickett	5 mi. SE. of Byrdstown	1,742	M. Mis	Knox (Ꞓ-Ord)	Tennessee Oil & Refining Co.	Old producer at 530 ft. drilled deeper. Oil show in Knox at 1670–1681 ft.
Robertson	8 mi. N. of Springfield	874	M. Mis	Sil	Leeper Oil Co.	Tested Silurian and Devonian on northern Highland Rim
Scott	5 mi. NW. of Oneida	850	Pen	Chester (Mis)	A. J. Brown et al.	Free oil at 850 ft. in Mississippian. To be tested
Scott	At Oneida	1,598	Pen	Osage (Mis)	Oneida Improvement Co.	Gas well. Rock pressure 275 lb.
Shelby	4 mi. S. of Millington	2,860	Recent	Igneous (Age?)	Lion Oil Refining Co.	
Stewart	3 mi. NW. of Dover	1,805	M. Mis	Stones River (Ord)	W. W. Dameron et al.	Tested pre-Knox section on northern Highland Rim
Wayne	2 mi. N. of Clifton	1,125	Trenton (Ord)	Knox (Ꞓ-Ord)	Clifton Oil Co.	Well-defined surface structure

TABLE 3.—*Physiographic Distribution of Wells Drilled in Tennessee in* 1941

Physiographic Division	County	Wildcat	In Proven Fields	Oil Wells	Gas Wells
East Tennessee	Anderson	1	0	0	0
Cumberland Plateau	Scott	1	1	1	1
Eastern Highland Rim	Clay	1	0	0	0
	Fentress	2	1	0	2
	Pickett	1	0	0	0
	Putnam	1	0	0	0
Northern Highland Rim	Dickson	1	0	0	0
	Macon	1	1	0	1
	Robertson	3	0	0	0
	Stewart	1	0	0	0
Central Basin	Davidson	1	0	0	0
Western Valley	Hardin	1	0	0	0
	Wayne	2	0	0	0
Mississippi Embayment	Lauderdale	1	0	0	0
	Shelby	1	0	0	0

Northern Highland Rim.—There were seven completions in the northern Highland Rim, one of which was a small gas well. An 874-ft. well in northern Robertson County tested the "Corniferous" horizons productive in Allen and Simpson Counties, Kentucky, to the north. The structural conditions are unknown. A test in central Stewart County was abandoned at 1805 ft. without reaching the Knox dolomite group. Two of these tests were drilled on pronounced surface structures previously mapped by geologists of this division.

Mississippi Embayment.—A test drilled by the Pure Oil Co. on a seismograph high in northeast Lauderdale County was abandoned at 1389 ft., in Paleozoic rocks possibly of Cambro-Ordovician age. No shows of oil or gas were encountered. A test in northern Shelby County encountered igneous material at 2710 ft. and was abandoned at 2860 ft. The samples consist of quartz, alkali feldspar, and abundant hornblende.

LEASING

There was little leasing activity in the state during the year. In the Cumberland Plateau area several sizable blocks of acreage were renewed by one of the major oil companies. In Middle Tennessee a few blocks were assembled, largely by local capital. There was no significant leasing in the Mississippi Embayment area, although there were renewals, some by the major companies.

Development and Production in East and East Central Texas in 1941

By D. V. Carter,* and Dan C. Williams, Jr.*

The four new oil-field discoveries made in the East and East Central Texas districts during 1941 were the East Long Lake field, Anderson County; Pickering field, Shelby County; Pleasant Grove field, Rusk County, and Tri-Cities field, Henderson County. The discovery of oil production in the Pettit lime of the Lower Glen Rose was made in the Groesbeck (Barron) field in Limestone County and the Willow Springs field in Gregg County. Important extensions were made to the Pittsburg field, in Camp County, the Chapel Hill field, in Smith County, and the Hawkins field, in Wood County. The Hawkins field was extended sufficiently to more than double the number of proved surface acres. As usual the East Texas field led the district in the number of completions for the year. The second most active field during the year was the Hawkins field, with 250 new wells completed. The third most active was the Long Lake field, in which 50 wells were completed. Approximately 964 wells were completed in the district during 1941.

Production and Proration

The district is credited with having produced 163,566,695 bbl. of oil and distillate during the year. This represents a decrease of 4 per cent from the 170,424,685 bbl. of oil and distillate produced during the preceding year. The production of 130,378,620 bbl. of oil and distillate from the East Texas field represents 79.7 per cent of the total production of the district; that is, 6.3 per cent less than the production for the year 1940. The district had an estimated basic daily allowable of 614,982 bbl. of oil on Dec. 31. Approximately 33 per cent of the state's annual production was produced in the district, compared with 34.9 per cent for 1940.

Since the majority of the fields in this district are subject to proration, any change in the annual production is attributable largely to changes in proration schedules and number of shutdown days. Fields subject to shutdown days were closed in for 113 days during the year, with the exception of the East Texas field, which was shut down 111 days.

An order was promulgated by the Oil and Gas Division of the Texas Railroad Commission for encouraging the disposal of salt water and reservoir-pressure maintenance in the East Texas field.

Discoveries

Tex Harvey Oil Company's No. 1 S. E. J. Cartmel was completed as the discovery well for the East Long Lake field, Anderson County. Production was found in the Woodbine sand, the horizon from which the Long Lake field produces.

The Pickering field, Shelby County, secures its production from the Nacatoch sand, found at an approximate depth of 1510 ft., in A. E. McKiernan's No. 1, Pickering Lumbering Co. This field is in an area near the state line in which a number of relatively unimportant and

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* Chief Petroleum Engineer and Petroleum Engineer, respectively, Magnolia Petroleum Co., Dallas, Texas.

TABLE I.—*Oil and Gas Production in East and East Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
1	Barron,[1] *Limestone*	1939	0	2*yy*	2,140	1,414
2	Bazette, *Navarro*	1939	100	0	156,592	49,627
3	Boggy Creek, *Anderson, Cherokee*	1927	960	0	5,040,590	75,404
4	Bolivar, *Denton*	1937	600	200	12,928	2,142
5	Bosque, *South, McLennan*	1902	2,500	0	110,245	4,297
6	Buffalo,[2] *Leon*	1934	10	7,500	12,613 17,387	2,950 0
7	Carthage,[1,5] *Panola*	1936	0	2,450*y*	152,504	70,973
8	Cayuga,[2] *Anderson, Henderson, Freestone*	1934	4,000	9,000	1,414,824C 21,767,710	528,564C 4,206,469
9	Cayuga (Trinity),[2] *Anderson, Henderson, Freestone*	1938	40	*y*	267,554C 15,769	76,179C 5,475
10	Chapel Hill,[2] *Smith*	1938	2,600	6,000	573,069 206,601	306,549 153,697
11	Collinsville, *Grayson*	1938	100	0	31,380	4,448
12	Corsicana,[6] *Navarro*	1895	6,710	*y*	14,451,997	142,576
13	Currie,[7] *Navarro*	1921	475	*y*	6,903,385	35,176
14	East Texas,[2] *Cherokee, Gregg, Rusk, Smith, Upshur*	1930	136,000	2,000	12,060 1,711,262,851	827 130,377,793
15	Flag Lake, *Henderson*	1937	405	0	487,911	74,593
16	Ginter, *Angelina*	1936	60	0	31,602	6,676
17	Grapeland,[2] *Houston*	1936	30	6,000*y*	1,600,955C 110,845	490,121C 27,290
18	Groesbeck, *Limestone*	1913 1924 1941	*y* *y* 10	2,360*y* 60*y* 0	0 *y* 143	0 0 143
19	Hawkins,[2] *Wood*	1940	8,200	250[10]	4,642 1,453,294	4,642 1,452,844
20	Hemby (Elkhart),[1] *Anderson*	1938	0	1*yy*	3,969	502
21	Huntington, *Angelina*	1936	100	0	12,921	1,202
22	Joaquin,[1,15] *Shelby*	1931	0	6*yyy*	101,975C	36,279C
23	Lone Star, *Cherokee*	1938	100	*y*	36,894	13,015
24	Long Lake,[2] *Anderson, Freestone, Leon*	1933	10,000	*y*	3,197,337C 4,485,854	1,558,267C 1,269,395
25	Long Lake, *East, Anderson*	1941	300	*y*	51,992	51,992
26	Lott, *Falls*	1937	3*yy*	0	30,769	3,492
27	Marion County (Shallow)	1939	670	*x*	226,114	103,202
28	Mexia, *Limestone*	1920	3,920	*y*	97,827,830	576,993
29	Nacogdoches, *Nacogdoches*	1865	1,000*y*	0	432,798*y*[16]	1,875[16]
30	Navarro Crossing,[2] *Houston*	1938	1,040	2,410	2,375 591,854	59 185,534
31	Nigger Creek, *Limestone*	1926	170	*y*	2,999,466	27
32	Oakwood,[2] *Leon*	1939	80	1,000	231 14,331	0 0
33	Opelika,[2] *Henderson*	1937	*x*	7,000*y*	1,583,706C 19,314	1,422,781C 41
34	Panola (Bethany),[2,15] *Panola*	1921	60	23,000*y*	20,344 57,890	11,112 7,109
35	Percilla, *Houston*	1937	1*yy*	*y*	29,551	0
36	Pickering, *Shelby*	1941	20	0	797	797

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[b] Footnotes to column heads and explanation of symbols are given on page 250.
[1] Distillate field.
[2] Oil and distillate field. Upper figure distillate production; lower figure oil production. C indicates cycling plant.
[5] Includes Hull and Pulaski Ferry.
[6] Includes Mildred, Angus-Edens, Hodge, Burk-Rice, Oil Ridge and Old Powell shallow.
[7] Includes North Currie.
[10] Woodbine gas area only. Sub-Clarksville probably covers at least one half of entire field.
[15] Field extends into Louisiana.
[16] Includes production from Chireno and Jennings fields.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
				Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
1	1,361	973	5	2	0	0	0	5	0	0	2,310	1,975		61.0	
2	*x*	*x*	8	0	0	0	7	0	6	1	1,300*y*	*y*		42.0	
3	*x*	*x*	33	0	0	0	17	0	0	17	1,680*y*	*y*		38.5	
4	*x*	*x*	10	0	1	0	1	3	0	1	*y*	*y*		40.2	
5	*x*	*x*	59*y*	0	0	3	49	0	0	46	*y*	*y*		41.0	
6	6,186	1,420	10	0	1	1	0	9	0	0	2,185 2,289	1,887[3] 2,230[4]		48.0 24.7	
7	8,897	4,200	11	3	0	0	0	11*y*	0	0	*y*	*y*		55.5 64.7 61.0	
8	90,167	23,225	332	16	3	0	281	51	150	131	1,750	1,362	PM	63.0 28.6	
9	20,258	3,779	6	2	0	0	1	5	1	0	*y*	*y*	PM	*y* 57.0	
10	9,044	4,984	24	12	0	0	15	9	14	1	2,900 *y* *y*	*y* *y* *y*		74.7 62.8 43.0	
11	*x*	*x*	2	0	0	0	2	0	0	2	*y*	*y*		29.3	
12	*x*	*x*	2,941*y*	0	11	0	616	0	0	616	*y*	*y*		27.5	
13	*x*	*x*	55*y*	1	0	0	14	0	0	14	*y*	*y*		40.5	
14	646,176[8]	49,522[8]	27,379	475	578	260*y*	26,078	5	17,666	8,152	1,620	1,026		58.0 39.0	
15	*x*	*x*	22	0	2	0	11	0	0	11	1,394	*y*		38.0[9] 45.0	
16	*x*	*x*	4	0	0	0	4	0	0	4	*y*	*y*		20.9	
17	19,518	16,160	39	15	0	0	1	31	1	0	2,200	2,100	PM	63.8 43.5	
18	11,800*y*	*y*	30*y*	0	0	0	0	*x*	0	0	275	*y*		Gas	
	x	*x*	5	0	0	0	0	3	0	0	875	*y*		Gas	
	x	*x*	1	1	0	0	1	0	1	0	*y*	*y*		35.7	
19	454	454	251[11]	250	0	1	247	3[11]	242	5	*y* 1,990[12]	*y* 1,934[13]		15–30[14]	1.6
20	1,147	72	2	0	0	1	0	1	0	0	2,200	*y*		59.2	
21	*x*	*x*	12	0	1	0	1	0	0	1	*y*	*y*		23.6	
22	20,659	10,413	24	0	0	7	0	7	0	0	2,550	*y*		37.0 48.0	
23	*x*	*x*	3	0	1	0	1	0	0	1	1,375	*y*		35.0	
24	67,700	14,903	224	50	0	3	140	83	121	19	2,440	2,192	PM	63.0 41.0	
25	*x*	*x*	11	11	0	0	11	0	11	0	*y*	*y*		43.0	
26	*x*	*x*	4	0	2	0	3	0	0	3	*y*	*y*		29.3	
27	*x*	*x*	44	6	7	0	38	0	0	38	*y*	*y*		40.0	
28	*x*	*x*	573*y*	11	8	0	217	0	5	212	*y*	*y*		35.0	
29	*x*	*x*	50*y*	0	1	0	39	0	0	39	*y*	*y*		23.0	
30	5,029	5	30	1	0	5[17]	21	2	21	0	2,700*y*	2,600[18]		41.0 37.5	
31	*x*	*x*	75	0	0	1	1	0	0	1	*y*	*y*		40.0	
32	51	0	6	0	0	2	2	1	0	0	*y*	*y*		*y* 36.0	
33	12,086	9,251	11	5	0	1	1	9	0	0	3,250 *y*	*y* *y*		58.7 38.9	
34	152,031	1,768	352	1	0	0	4*y*	83*y*	0	4*y*	*y*	*y*		60.0 28.0	
35	744	0	2	0	1	0	0	0	0	0	*y*	*y*		41.0	
36	*x*	*x*	1	1	0	0	1	0	0	1	*y*	*y*		40.0	

[3] South dome.
[4] North dome.
[8] Includes estimate of gas produced with oil and gas produced from gas wells.
[9] Upper sand.
[11] Includes three gas wells producing from Sub-Clarksville.
[12] Corrected to 4075 ft. subsea.
[13] Nov. 15, 1941.
[14] Field shows marked gravity segregation.
[17] Gas wells.
[18] May 1, 1941.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	L. Glen Rose	CreL	L	*y*	5,584	5,611	25	AF	Travis Peak	6,051
2	Woodbine	CreU	S	21–25	2,992	3,008	15	AF	Woodbine	3,008
3	Woodbine	CreU	S	25	3,632	3,666	34	Ds	Fredricksburg	4,648
4	Cisco	Pen	S, L	*y*	1,630	1,683	25	AF	Ellenburger	2,530
5	Basal Walnut	CreL	DL	*y*	450	475	3	AF	Trinity	1,800*y*
6	Woodbine	CreU	S	20	6,150 5,285	6,175 5,695	22[3] 44[4]	D	CreL (Washita)	6,300
7	L. Glen Rose	CreL	OL	18–21	4,984	5,040	20	MC	Travis Peak	6,019
	L. Glen Rose		L	23	5,930	5,940	10	D		
	L. Glen Rose (Pettit)		OL	*y*	5,825	5,905	*y*	MC		
8	Woodbine	CreU	S	25	3,680	3,758	Gas 54 Oil 24	AF	Trinity	9,085
9	L. Glen Rose	CreL	L	20	7,412	7,612	10	AF	Trinity	7,614
10	Paluxy	CreL	S	21	5,600	5,700	50*y*	A	Travis Peak	8,600
	L. Glen Rose (Rodessa)		OL	10–18	7,400	7,500	25*y*			
	L. Glen Rose (Pettit)		OL		8,000	8,100	24*y*			
11	Strawn	Pen	S	*y*	3,848	4,219	20	ML	Strawn	4,219
12	Nacatoch Corsicana (Wolf City)	CreU	S	*y*	800	1,260	12–20	AF	Woodbine	3,570
13	Woodbine	CreU	S	22	2,930	2,990	20	AF	Woodbine	3,646
14	Woodbine	CreU	S	25	3,632	3,665	35	Shoreline	Paluxy	5,020
15	Woodbine	CreU	S	21–25	3,050	3,075	5	AF	Travis Peak	6,518
16	Carrizo	Eoc	S	*y*	2,186	2,200	10	ML	Wilcox	2,265
17	Woodbine	CreU	S	25	5,976	6,083	25	A	Woodbine	6,300
18	Nacatoch	CreU	S	25.5	710*y*	750*y*	40*y*	AF		
	Woodbine	CreU	S	20	2,945	2,960	15	AF	Woodbine	3,208
	L. Glen Rose (Pettit)	CreL	L	*y*	5,685	5,776	*y*	AF	L. Glen Rose (Pettit)	5,796
19	Sub-Clarksville Woodbine	CreU	S	*y* 27	4,073 4,350	4,225 4,850	Gas 150*y* Oil 100*y*	AF	Paluxy	6,535
20	Woodbine	CreU	S	25	5,409	5,422	*y*		Woodbine	5,487
21	Queen City	Eoc	S	*y*	1,458	1,483	8	ML	Mount Selman	1,490
22	U. Glen Rose L. Glen Rose	CreL CreL	L	*y*	4,097 5,070	4,107 5,138	10 30	D	Glen Rose	5,138
23	Woodbine	CreU	S	*y*	4,006	4,010	4	Af	Woodbine	4,015
24	Woodbine	CreU	S	25	5,170	5,250	Gas 24*y* Oil 8	A	Trinity	5,417 9,966
25	Woodbine	CreU	S	24	5,335	5,385	8	D	Woodbine	5,417
26	Buda, U. Washita	CreL	DL	*y*	1,250	1,275	10	Af	Edwards	1,500
27	Tokio	CreU	S	*y*	2,336	2,346	10	A	Tokio	2,346
28	Woodbine	CreU	S	25	3,000	3,085	50	AF	CreL or older	8,847
29	Weches	Eoc	SH	*y*	80	100	*y*	ML	CreL	5,484
30	Woodbine	CreU	S	22	5,750 5,874	5,900 5,895	Gas 31 Oil 7	Af-D	Woodbine	5,968
31	Woodbine	CreU	S	25	2,820	2,870	15	AF	Woodbine	3,509
32	Woodbine	CreU	S	*y*	5,838	5,841	3	D	Woodbine	5,913
33	L. Glen Rose (Rodessa) U. Glen Rose	CreL	LS	18–20	8,170 7,195	8,180 8,028	40	AF	L. Glen Rose (Pettit)	9,740
34	Various[19]	CreU CreL	S, L	*y*	1,100	5,700	40	A	Salt	11,303
35	Woodbine	CreU	S	*y*	5,665	5,670	5	A	CreL (Del Rio)	6,634
36	Nacatoch	CreU	S	*y*	1,475	1,510	20	ML	Washita	3,343

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[19] Nacatoch 1100 ft., gas; Buckrang 1700, oil; Barlow 2300, gas; Adams 2650, gas; Tiller (Paluxy) 2300, gas; Werner 3600, gas; Jeter (Glen Rose) 5700, gas; Pettit, gas.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
37	Pittsburg, *Camp*	1940	560	0	47,106	35,876
38	Pleasant Grove, *Rusk*	1941	50	0	18,105	18,105
39	Post Oak (Chilton), *Falls*	1922	1*yy*	0	178,760	573
40	Potter (Caddo),[15] *Marion*	1905	980	0	7,679,730	28,630
41	Pottsboro, *Grayson*	1928	20	1*yyy*	10,865	1,208
42	Powell,[20] *Navarro*	1923	2,600	*y*	111,186,487	585,304
43	Red Lake,[2] *Freestone*	1934	0	3*yyy*	1,732 1,605	121 0
44	Richland, *Navarro*	1924	440	*y*	6,656,626	15,722
45	Rodessa, (Dees-Young), *Cass*	1935	5,010	3,250	28,102,671	2,376,135
46	(Gloyd), *Marion*	1937	4,035	10,150	10,547,620	1,701,893
47	(Gloyd), *Cass*	1936	1,885	10,150	8,707,942	697,785
48	Total[2,15]		10,930	23,550	48 358,233[21]	4,775,813[21]
49	Rowe and Baker, *Henderson*	1939	80	0	73,944	23,931
50	Shelbyville, *Shelby*	1917	50	0	13,611	35
51	Sulphur Bluff, *Hopkins*	1936	855	0	8,037,675	1,579,204
52	Talco, *Franklin*, *Titus*	1936	7,850	0	48.123,783	9,032,391
53	Tehuacana, *Limestone*	1940	60	0	27,524	18,394
54	Tri-Cities, *Henderson*	1941	*y*	160*y*	5,939	5,939
55	Trinity, *Houston*	1934	280	0	1,755,632	137,086
56	Van (deep), *Van Zandt*	1929	4,520	60	129,535,480	3,669,738
57	Van (shallow), *Van Zandt*	1933	200	0	311,712	21,553
58	Total		4,720	60	129,847,192	3,691,291
59	Waskom,[2,15] *Harrison*	1924	1,500	6,000	136,538 91,680	63,312 14,183
60	Willow Springs,[2] *Gregg*	1938	40		48,030 2,065	31,685 2,065
61	Wortham,[24] *Freestone*	1924	715	0	22,771,643	161,284
62	Total				9,136,598 2,252,767,810*y*	4,606,337 158,960,358

ABANDONED FIELDS

		Year Discovery	Year Abd.				
63	Beulah (Lee-Tex), *Angelina*	1935	1935	10	0	750	0
64	Camp Hill, *Anderson*	1935	1937	200	0	289,030	0
65	Cedar Creek, *Limestone*	1927	1930	30	0	330,600	0
66	Chatfield, *Navarro*	1905	1910	0	150	0	0
67	DeBerry, *Panola*	1926	1932	100	50	29,166*y*	0
68	Kosse, *Limestone*	1922	1922	10	0	33,000	0
69	Marlin-Satin, *Falls*	1931	1939	10	0	12,830	0
70	Mexia (Shallow), *Limestone*	1912	1920*y*	0	4,094	0	0
71	Mount Calm, *Hill*	1929	1931	*x*	*x*	27,991	0
72	Redland, *Angelina*	1939	1940	10	0	60	0
73	Rusk, *Cherokee*	1934	1939	200	0	261,134	0
74	Tacoma, *Panola*	1933	1938	40	0	15,750	0
75	Witherspoon-McKie, *Navarro*	1915	1935	400	0	810,495	0
76	Total Abandoned Fields					1,810,806	0
77	Grand Total					9,136,598 2,254,578,616*y*	4,606,337 158,960,358

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[20] Includes shallow production discovered and produced since 1923 in the Powell Woodbine producing area.
[21] Production by horizons estimated. Includes distillate production.
[24] Wortham Shallow discovered in 1912 included with Wortham.

TABLE I.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
				Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
37	*x*	*x*	4	3	0	0	4	0	3	1	3,408	*y*		42.3	
38	*x*	*x*	5	5	0	0	5	0	4	1	*y*	*y*		40.0	
39	*x*	*x*	26*y*	0	0	0	1	0	0	1	*y*	*y*		33.0	
40	*x*	*x*	78*y*	12	7	2	28	0	0	26	*y*	*y*		40.0	
41	*x*	*x*	15	0	0	0	1	0	0	1	300	*y*		38.8	
42	*x*	*x*	764	1	1	0	146	0	0	146	800*y*	*y*		37.8	
43	1,945	111	3	0	0	0	0	2	0	0	1,855	1,780		*y*	
44	*x*	*x*	111	3	2	0	4	0	0	4	*y*	*y*		38.4	
45	99,926	11,405	278	0	0	33	231	9	46	185	2,700	850		43.2	
46	36,380	7,999	165	0	3	1	144	17	118	26	2,677	1,300		42.0	
47	34,749	5,024	72	0	3	2	57	4	29	28	2,700	615	RP	42.0	
48	171,055	24,428	515	0	6	36	432	30	193	239					
49	*x*	*x*	4	0	1	1	3	0	0	2	*y*	*y*		31.7	
50	*y*	*y*	2	0	1	0	0	0	0	0	*y*	*y*		37.0	
51	0	0	73	0	0	0	73	0	3	70	1,900	*y*		22.4	
52	*y*	*y*	818	47	14	5	752	0	17	735	1,920	*y*		20.6	
53	*x*	*x*	8	0	0	0	3	0	0	3	*y*	*y*		21.0	
54	84*y*	84*y*	1	1	0	0	1	0	1	0	3,650	3,650		59.6	
55	*y*	*y*	20	0	0	0	15	0	0	15	870	*y*		24.0	
56	*y*	*y*	581	4	2	3	561[22]	2	335	226	1,230*y*	1,100[23]		34.0	
57	*y*	*y*	39	1	3	2	28	0	0	28	*y*	638		31.0	
58	*y*	*y*	620	5	5	5	589	2	335	254					
59	106,957	7,176	245	5	*y*	6	19	223	0	17	*y* 2,040 2,334	*y* *y* 2,212		*y* 61.8 59.5	
60	4,319	2,968	8	4	0	0	1	5	0	1	2,950	2,600	PM	*y* 56.9 38.7	
61	*x*	*x*	339	15	0	2	32	0	0	30	*y*	*y*		29.0 37.0	
62	1,357,668*y*	175,896	36,310*y*	964	654	342*y*	29,934*y*	583*y*	18,795	10,866					
	ABANDONED FIELDS														
63	0		1		0						200*y*	*x*		24.0	
64	*y*		10*y*		0						1,950	*x*		40.6	
65	*y*		14		0						*x*	*x*		37.0	
66	4,750		15		0						250	*x*		Gas	
67	*x*		22		0						757	*x*		46.0	
68	0		1		0						*x*	*x*		32.0	
69	0		2		0						*x*	*x*		34.2	
70	20,200*y*		50*y*		0						276	*x*		Gas	
71	*x*		2		0						*x*	*x*		31.3	
72	0		1		0						*x*	*x*		23.0	
73	0		5		0						*x*	*x*		42.0	
74	0		3		0						*x*	*x*		46.0	
75	0		85		0						*x*	*x*		19.0	
76	24,950		211		0										
77	1,382,618*y*	175,896	36,521*y*	964	654	342*y*	29,934*y*	583*y*	18,795	10,866					

[22] Three wells producing from Sub-Clarksville.

[23] Brown sand.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
37	Travis Peak	CreL	S	12–19	7,948	8,200	62	A	Travis Peak	8,203
38	Woodbine	CreU	S	20	4,055	4,062	5	Fault and Shoreline	Woodbine	4,277
39	Buda	CreL	L	*y*	1,025	1,046	10	AF	Trinity	3,567
40	Nacatoch-Tokio	CreU	S	20	1,025 2,300	1,040 2,366	*y* 15	A	CreU, (Tokio)	2,366
41	Trinity (Basal)	CreL	S	*y*	830	838	8	MU	Ordovician, or Older	6,004
42	Woodbine	CreU	S	25	2,925	3,000	40	AF	Trinity	6,506
43	Woodbine	CreU	S	20	4,850	4,950	25	AF	Woodbine	5,002
44	Woodbine	CreU	S	25	2,975	3,040	20	AF	Glen Rose	5,414
45	L. Glen Rose (Dees-Young)	CreL	L	17	5,794	6,040	25	AF		
46	L. Glen Rose (Gloyd)	CreL	L	15	6,044	6,094	20	AF		
47	L. Glen Rose (Gloyd)	CreL	S, L	16	5,914	6,000	20	AF		
48									Salt, CreL, or Older	11,484
49	Woodbine	CreU	S	20*y*	3,140	3,149	6	AF	Woodbine	3,149
50	Blossom	CreU	S, L	*y*	2,690	2,700	10	ML	Georgetown	3,400
51	Paluxy	CreL	S	25	4,487	4,523	36	AF	Glen Rose	6,600
52	Paluxy	CreL	S	20	4,200	4,300	35	AF	Glen Rose	5,903
53	Woodbine	CreU	S	*y*	2,640	2,700	10	AF	Georgetown	2,825
54	L. Glen Rose (Rodessa)	CreL	L	*y*	7,608	7,641	20*y*	A	Travis Peak	8,474
55	Carriso	Eoc	S	*y*	1,995	2,013	10	Ds	Salt dome material	3,855
56	Woodbine	CreU	S	*y*	2,682	2,950	268	AF		
57	Nacatoch	CreU	S	*y*	1,200	1,220	20	AF		
58									Travis Peak	7,501
59	Nacatoch, Blossom, Glen Rose, Travis Peak	CreU	Ls S L	*y* *y* 10–15	800	6,160	15–40	A	Travis Peak	6,340
60	L. Glen Rose (Rodessa) L. Glen Rose (Pettit) L. Glen Rose (Pettit)	CreL	OL	*y* *y* *y*	6,768 7,244 7,298	6,770 7,268 7,308	Gas 2*y* Gas 35*y* Oil 10*y*	D	Cotton Valley	10,284
61	Nacatoch Woodbine	CreU	S	*y* 25	1,361 2,990	1,371 3,050	6 35	AF AF	Glen Rose	4,825
62										
	ABANDONED FIELDS									
63	Queen City	Eoc	S	*x*	2,045	2,053	5	ML	Carriso	2,324
64	Sub-Clarksville, (Eagle Ford); Woodbine	CreU	S, SH	*y*	5,054	5,059	5	AF	L. Glen Rose	8,383
65	Woodbine	CreU	S	25	2,885	2,940	10	AF	Woodbine	3,310
66	Corsicana (Wolf City)	CreU	S	*x*	880	1,020	13	A	Woodbine	3,057
67	Blossom	CreU	S, H	*y*	1,990	2,087	*y*	ML	Blossom	2,125
68	Unknown			*x*	*x*	3,767	*x*	Crev	Glen Rose	6,056
69	Buda	CreL	L	20	1,000	1,160	20	AF	Glen Rose	1,409
70	Nacatoch	CreU	S	25.5	710*y*	750*y*	40*y*	AF	CreL or older	8,845
71	Austin	CreU	C	*x*	607	700	8	F	Travis Peak	3,398
72	Wilcox	Eoc	S	*y*	1,021	1,032	8	ML	Wilcox	1,032
73	Woodbine	CreU	S	20	5,120	5,125	10*y*	MU	Woodbine	5,302
74	Blossom	CreU	S	*y*	2,073	2,085	10	ML	Blossom	2,302
75	Nacatoch	CreU	S	14	825	875	19	AF	Woodbine	3,480
76										
77										

comparatively shallow oil fields have been discovered.

The Pleasant Grove field, in southwest Rusk County, produces on the upthrown side of a fault from the Woodbine sand, which pinches out to the east.

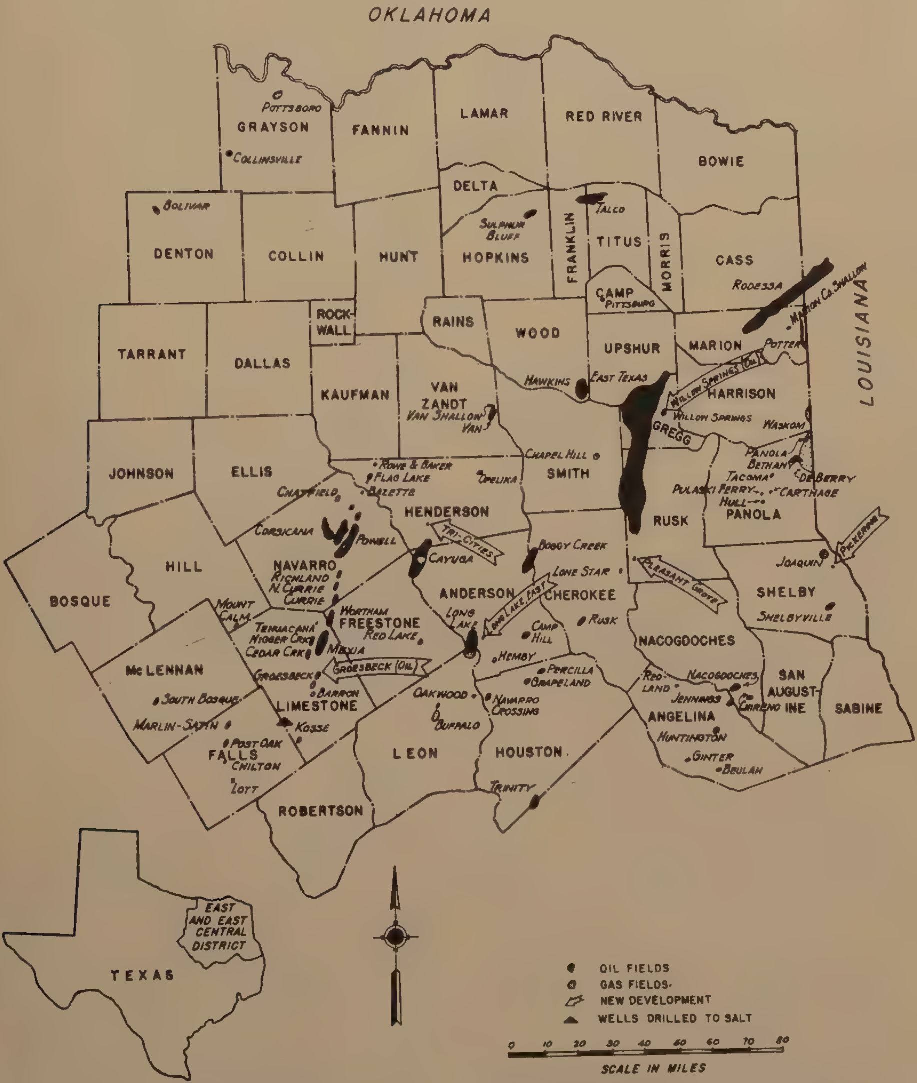

FIG. 1.—LOCATION OF OIL AND GAS FIELDS, EAST AND EAST CENTRAL TEXAS. (Texas Railroad Commission Districts 5 and 6)

British American Oil Company's No. 1 M. G. Young, Henderson County, was completed in the "Rodessa" limestone of the Lower Glen Rose, as the discovery well for the Tri-Cities field.

The three most important extensions to the existing oil and gas fields in this district during the year were made to the Hawkins, Chapel Hill and Pittsburg fields. The size of the Hawkins field increased from 4000 to 8200 surface acres and at the end of the year approximately 247 oil wells were producing in the field, of which 242 wells were flowing. This field, as defined late in 1941, is almost circular in shape, with a slight elliptical bulge, the long axis of which extends in a northeast and southwest direction. Further development during 1941 revealed the presence of a major fault in the southeast quarter of the field, parallel to the long axis with the upthrown side on the east. This condition has resulted in the drilling of numerous oil wells in an area that would have been located structurally low had it not been for the presence of the fault. In the immediate vicinity of the fault the net oil-saturated thickness of the Woodbine sand is severely reduced.

TABLE 2.—*Summary of Drilling Operations in East and East Central Texas*

Discoveries, Extensions, and Important Wildcats Drilled during 1941

County	Drilled By	Well Number and Farm	Survey	Producing Formation
Anderson	Tex Harvey	1, S. E. J. Cartmel	E. Ewing	Woodbine
Camp	Talco Asphalt and Ref. Co.	1, Shell-McKenzie	L. Williams	Travis Peak
Gregg	Humble Oil and Ref. Co.	2, Horton-Dickson	H. Frost	Pettit
	Lone Star Gasoline Co. & Rogers Lacy	1, Horton-Dickson	J. L. T. Meredith	L. Glen Rose (Rodessa)
Henderson	British American Oil Co.	1, M. G. Young	J. Rice	L. Glen Rose (Rodessa)
Hopkins	W. B. Hinton & Talco Asphalt & Ref. Co.	1, S. M. Long	U. Acquier	
Limestone	B. F. Weekly et al.	A-2, W. C. Barron	E. Mabry	Pettit
	Farrel Drilling Co.	1, J. R. Gilliam	J. S. Spencer	
Red River	Magnolia Petr. Co.	1, J. N. Henry	M. E. P. & P. R. R. No. 103	
Rusk	M. D. Bryant	1, L. H. Evans	G. May	Woodbine
	O. W. Killam	1, E. Bass	J. I. Sanchez	
Shelby	Grady Vaughn	1, Frost Lumber Co.	J. Buckley	
	A. E. McKiernan	1, Pickering Lumber Co.	G. H. Patterson	Nacatoch
Wood	Humble	1, E. Dagnell	W. Parker	Sub-Clarksville
	Sells Petr. Co.	1, J. L. Beckman	G. W. Cowan	

Discoveries, Extensions, and Important Wildcats Drilled during 1941

Depth Completed, Ft.	Total Depth, Ft.	Deepest Horizon Tested	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
5,387	5,387	Woodbine	365.25	1.560	¼	1,925	1,560	Discovery well, Long Lake, East field
8,200	8,203	Travis Peak	98.44					Extension of Pittsburg field
7,308	7,309	Pettit	30.36	9.347	½	550	350	Discovery well, Pettit oil, Willow Springs field
6,680	7,327	Pettit		60.000		2,730		Discovery well, Rodessa gas, Willow Springs field
7,641	8,474	Travis Peak	354.06	4.978	⅜	2,740	1,870	Discovery well, Tri-Cities field
	4,895	Paluxy						Dry hole—small amount oil
5,786	5,796	Pettit	22.19	1.370		800	500	Discovery well, Pettit oil, Groesbeck field
	4,869	Paleozoic						Dry hole
	4,788	Paleozoic						Dry hole
4,065	4,100	Woodbine	300.00		¼	1,265	500	Discovery well, Pleasant Grove field
	4,372	Woodbine						Dry hole—pumped oil and salt water from Nacatoch 2910 to 2965 ft.
	8,243	Travis Peak						Dry hole
1,510	3,343	Washita	31.00					Discovery well, Pickering field
4,073	4,515	Woodbine		3.280	3⁄16	1,775	1,685	Gas well, Sub-Clarksville, Hawkins field
	7,501	Eagleford						Dry hole

The Chapel Hill field was extended to the north and 12 oil wells were completed in the Pettit limestone of the Lower Glen Rose during the year.

The Pittsburg field, Camp County, had five producing oil wells at the end of the year. The Talco Asphalt and Refining Company's No. 1 Shell-McKenzie well extended the field about a mile to the west.

CHANGES IN PRICES OF CRUDE OIL

In general, crude-oil prices were revised upward. At the end of 1941 the following prices, per barrel, were in effect: East Texas, $1.25; Talco, $0.79; Cayuga, $0.90; Long Lake, $1.23; Hawkins, $0.80, for gravity below 20, with a $0.02 differential up to and including 25 gravity and above $0.92; Navarro Crossing, $0.97 for 25° gravity and below, with a $0.02 differential up to 40° gravity, 40° and above, $1.27; Mexia, $0.95, for gravity below 25°, $0.97 for 25° gravity, up to and including 25.9°, with a $0.02 differential up to 40° gravity, 40° and above, $1.27; Rodessa, $0.88 below 25° gravity, with a $0.02 differential to 40° gravity, 40° and above $1.20.

CYCLING AND PRESSURE-MAINTENANCE PROJECTS AND DISPOSAL OF SALT WATER

During the year cycling plants were placed in operation by Geier Brothers and Jackson in the Grapeland field, Houston County, and Lone Star Gasoline Co. and Rogers Lacy in the Willow Springs field, Gregg County. There were 14 cycling plants and 4 repressuring plants operating in six fields in the district at the end of the year.

An increase in the rate of decline of reservoir pressure for the East Texas field during the year emphasized the necessity for the return of salt water produced from the Woodbine sand, and was so recognized by the Oil and Gas Division of the Railroad Commission. Consequently, several hearings were held, which resulted in the promulgation of a salt-water disposal order, which allows an operator to receive a bonus of one barrel of oil for each fifty barrels of salt water returned. A later order issued by the Railroad Commission allows an operator to entirely shut in a well producing an amount of salt water in excess of 100 bbl. and to transfer the shut-in well's oil allowable to other wells on the same lease, or to wells on other leases belonging to the same operator, as a further incentive for reducing the amount of salt water not returned, and thus aiding in the protection of the reservoir energy for this field.

CONSTRUCTION OF OIL PIPE LINES

Humble Pipe Line Co. completed 5 miles of 6-in. line from the Hawkins field, Wood County, south to a point on its Van-Longview main line. Later in the year this lateral was looped with a parallel 8-in. line.

TABLE 3.—*Production Statistics, East Texas Field**

Date, Year 1941	Average Reservoir Pressure at −3300 Ft., Lb. per Sq. In.	Production, Bbl. (42 U. S. Gal.)	Number of Days Shut Down
Jan. 8.	1,051.73	10,870,662	10
Feb. 1.	1,050.93	9,820,626	9
Mar. 1.	1,050.45	11,330,857	9
Apr. 1.	1,047.22	10,766,709	9
May 1.	1,047.64	11,255,662	9
June 1.	1,042.29	10,738,827	9
July 1.	1,034.63	10,280,662	11
Aug. 1.	1,038.48	10,777,708	10
Sept. 1.	1,038.90	10,267,320	10
Oct. 1.	1,038.56	11,279,811	9
Nov. 1.	1,030.46	11,253,471	8
Dec. 1.	1,029.46	11,735,478	8
	Average 1,041.73	Total 130,377,793	111

* Data from Texas Railroad Commission.

The Gulf Oil Co. completed a 4-in. pipe line for distillate, from the Opelika field, Henderson County, to its Big Sandy Station, near the town of Big Sandy, Upshur County—a distance of 34 miles.

GENERAL COMMENTS

A few days after the close of 1941 the discovery of oil production in the Smackover lime in the Midway field, Lafayette County, Arkansas, stimulated a widespread campaign for leases along the north and west sides of the East Texas Basin, from Columbia County, Arkansas, to Falls County, Texas, a distance of approximately 325 miles.

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TABLE 4.—*Oil-recovery Data on Older Woodbine Fields as of January* 1, 1942

Field	County	Cumulative Production, Bbl.	Proved Acres	Net Thickness, Ft.	Acre-feet	Cumulative Production, Bbl. per Acre-foot
Boggy Creek	Anderson, Cherokee	5,040,590	960	34	32,640	154
Cayuga	Anderson, Freestone, Henderson	21,767,710	4,000	24	96,000	227
Currie	Navarro	6,903,385	475	20	9,500	727
East Texas	Cherokee, Gregg, Rusk, Smith, Upshur	1,711,262,851	136,000	35	4,760,000	360
Flag Lake	Henderson	487,911	405	5	2,025	241
Mexia	Limestone	97,827,830	3,920	50	196,000	499
Nigger Creek	Limestone	2,999,466	170	15	2,550	1,176
Powell	Navarro	111,186,487	2,600	40	104,000	1,069
Richland	Navarro	6,656,626	440	20	8,800	756
Van (Deep)	Van Zandt	129,535,480	4,520	268	1,211,360	107
Wortham	Freestone	22,771,643	715	35	25,025	910
Cedar Creek*	Limestone	330,600	30	10	300	1,102
Rusk*	Cherokee	261,134	200	10	2,000	131

* Abandoned fields.

Oil and Gas Production in the Texas Gulf Coast during 1941

By P. B. Leavenworth* and Jack F. Harang*

Development during the year 1941 on the Texas Gulf Coast resulted in the discovery of 27 new fields as compared to 26 fields for the year 1940.

Drilling.—During the year, 1405 wells were drilled. Of this number, 1031 were completed as oil wells with 375,000 bbl. daily of new production; 50 were completed as gas wells and 324 were failures. The most active area was Jackson County, where 375 wells were drilled and 336 of them accounting for 190,000 bbl. daily of new production.

Types of Fields.—Of the 27 new fields, 14 are considered to be oil fields, 8 are listed as gas-distillate fields and 5 as gas fields. This may be compared to 26 fields found in 1940, of which 14 were oil fields and 12 gas-distillate fields.

Producing Sections.—Frio discoveries retained their predominant position by having 10 Frio fields discovered in comparison to 6 fields in the Wilcox, 4 in the Yegua, 5 in the Miocene and 2 in the Jackson. In the previous year 15 Frio fields were found, 4 in the Wilcox, 2 each in the Yegua, Cook Mountain and Miocene, and 1 in the Jackson.

Production.—Production increased over 1940 approximately 10 per cent, being 113,726,893 bbl. for the year 1941 and 104,127,247 bbl. for 1940. The statistics in Tables 1 and 2 include distillate and condensate as oil production because no separate reports have been compiled. It is hoped that this separation may be possible some day, but as a great many fields produce both oil and distillate and these are commingled in pipe lines, separation of statistics will be more difficult than for other areas.

New Fields

Big Hill, Jefferson County.—Stanolind Oil and Gas Company's No. 1 George D. Anderson was completed as a gas well from a Frio sand at 8705 to 8720 ft., on Dec. 24, 1941, after having been drilled to a depth of 9500 ft. Additional development is being carried on but it is not possible to evaluate this discovery at this time.

Brushy Creek Field, Lavaca County.—Shell Oil Corporation's No. 1 D. G. McManus was completed as the discovery well in the Brushy Creek field on Oct. 29, 1941, from a Wilcox sand through perforations at 7225 to 7230 ft., making gas and 180 bbl. of 59° gravity distillate. This well was bottomed at 10,998 ft. in the Wilcox. No statement can be made at this time as to the importance of this discovery.

Chenango Field, Brazoria County.—J. N. Rayzor et al. completed their No. 1 Sarah J. Christian through perforations at 8564 to 8572 ft. in a Frio sand, for 453 bbl. of 37.7° gravity oil, on Feb. 6, 1941, after having drilled to 9564 ft. Several wells were drilled in this area during the year but failed to establish important production. This is considered a minor discovery.

Clodine Field, Fort Bend County.—Providence Oil Company's No. 1 Hatfield was the discovery well of the Clodine field, being completed through perforations at 7499 to 7502 ft. for 108 bbl. of 51.2° gravity distillate, on June 19, 1941. The well was bottomed at 8090 ft. Several wells

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* Gulf Oil Corporation, Houston, Texas.

TABLE 1.—*Oil and Gas Production in Coastal Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941
1	Aldine, *Harris*	1939	50	200	44,425	13,028	0	0
2	Allen, *Brazoria*	1927	10	0	90,832	Abandoned		
3	Alta Loma, *Galveston*	1940	125	0	444,036	63,382	0	0
4	Amelia, *Jefferson*	1936	1,000	*y*	5,721,861	1,220,927	0	0
5	Anahuac, *Chambers*	1935	7,000	0	20,105,833	4,649,833	*y*	*y*
6	Angleton, *Brazoria*	1939	700	0	480,583	229,290	0	0
7	Aransas (McCampbell), *Aransas, San Patricio*	1936	2,340	*y*	10,895,158	1,954,795	*y*	*y*
8	Armour (McCroskey), *Matagorda*	1938	125	*y*	148,767	28,991	0	0
9	Arriola, *Hardin*	1932	100	*y*	2,222,214	170,076	0	0
10	Baileys Prairie, *Brazoria*	1940	*y*	*y*	203	*y*	0	0
11	Bammel, *Harris*	1936	2,200	0	483,559	42,818	*y*	*y*
	Barbers Hill, *Chambers:*							
12	2300 ft.	1916	500	0	72,736,905	3,079,407	0	0
13	5200 ft.	1928	Included with Shallow				0	0
	Batson, *Hardin:*							
14	4245 to 5625 ft.	1903	500	0	39,003,004	177,928	*y*	*y*
15	4900 ft. (New Batson)	1934	150	0	2,173,779	153,857	Included	
16	Bay City, *Matagorda*	1934	1,200	*y*	4,660,123	784,093	0	0
17	Beeville (Church), *Bee*	1935	20	0	1,000	*y*	*y*	*y*
18	Big Creek, *Fort Bend*	1922	240	*y*	9,959,581	143,306	0	0
19	Big Hill, *Jefferson*	1923	10	0	13,853	Depleted	*x*	0
20	Big Hill, *Matagorda*	1904	15	0	210,906	*y*	*y*	0
21	Blessings, *Matagorda*	1940	2,000	*y*	1,450	Gas-dist.	*y*	*y*
22	Blue Ridge, *Fort Bend*	1919	400	*y*	11,059,115	338,287	0	0
23	Boling, *Wharton*	1925	250	*y*	7,527,241	376,229	0	0
24	Bonnieview, *Refugio*	1939	*y*	*y*	4.580	*y*	*y*	*y*
25	Borden, *Wharton*	1940	150	*y*	38,628	23,428	0	0
26	Brenham, *Washington, Austin*	1926	50	*y*	381,791	4,082	0	0
27	Brookshire, *Waller*	1934	50	*y*	22,333	864	0	0
28	Brushy Creek, *Lavaca*	1941	40	*y*	*y*	*y*	*y*	*y*
29	Buckeye, *Matagorda*	1932	75	*y*	807,417	29,813	0	0
30	Burnell (South), *Karnes*	1937	*y*	*y*	1,118	*y*	*y*	*y*
31	Buttermilk Slough, *Matagorda*	1939	50	*y*	9,391	2,259	0	0
32	Ceasar, *Bee*	1934	520	*y*	1,004 513	34,431	*y*	0
33	Call, *Newton*	1937	100	*y*	11,016	0	0	0
34	Caplen, *Galveston*	1939	350	*y*	320,249	164.500	0	0
35	Cedar Point, *Chambers*	1938	400	*y*	1,067,206	263,468	0	0
36	Cheek, *Jefferson*	1937				See Lovell's Lake		
37	Chenango, *Brazoria*	1941	80	*y*	36,232	36,232	*y*	*y*
38	Chriesman (Red Bank), *Burleson*	1938	*y*	*y*	*y*	*y*	*y*	*y*
39	Chocolate Bayou, *Brazoria*	1939	500	*y*	164,262	119,868	*y*	*y*
40	Citrus Grove, *Matagorda*	1939	*x*	1,800	*x*	*x*	*y*	*y*
41	Clam Lake, *Jefferson*	1937	500	*y*	310,829	134,767	*y*	*y*
42	Clay Creek, *Washington*	1927	300	*y*	4,456,073	153,246	*y*	*y*
43	Clear Lake, *Harris*	1938	2,100	*y*	1,129,728	573,950	*y*	*y*
44	Cleveland, *Liberty*	1933	700	*y*	1,329,171	86,150	*y*	*y*
45	Clinton, *Harris*	1936	150	*y*	275,708	46,937	*y*	*y*
46	Clodine, *Fort Bend*	1941	450	*y*	36,449	36,449	*y*	*y*
47	Colletto Creek, *Victoria*	1934	260	520	1,341,938	117,243	*y*	*y*
48	Cologne, *Victoria*	1939	20	180	39,317	33,613	*y*	*y*
49	Coloma Creek, *Calhoun*	1941	80*y*	*y*	21,380	21,380	*y*	*y*
50	Conroe, *Montgomery*	1931	17,650	*y*	129,153,299	11,621,299	*y*	*y*
51	Cordele, *Jackson*	1938	420	850	2,038,401	488,111	*y*	*y*
52	Cotton Lake, South, *Chambers*	1936	1,000	*y*	2,222,348	650,016	*y*	*y*
53	Cotton Lake, *Chambers*	1937	175		764,654	88,026		

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[b] Footnotes to column heads and explanation of symbols are given on page 250.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
1	2	1	0	0	2	0	1	1	*x*	*x*	0	37–66	
2									200	*x*	0		
3	4	2	0	0	4	0	4	0	*y*	*y*	0	34–36	
4	120	0	11	0	109	0	109	0	925	*y*	0	27–29	
5	389	25	22	0	357	10	356	11	3,260	*y*	0	34.5	
6	8	1	0	0	8	0	8	0	*x*	*x*	0	50	
7	342*y*	6	24	0	316*y*	2*y*	292*y*	*y*	2,220	*x*	*y*	47	
8	5	0	2	*y*	3	0	1	2	2,000	*y*	*y*	33–37	
9	21	1	10	0	11	0	0	11	*x*	*y*	*y*	30–34	
10	1	0	0	0	*y*	0	*y*	*y*	*y*	*y*	*y*	27	
11	20	1	19	0	0	1	1	0	*x*	*y*	*x*	58	
12	423	21	271	0	152	0	31	121	*y*	*y*	0	25–29	
13	Included with above								296	*y*	0	27	
14	1,017	6	836	0	169	1	0	170		*y*	0	24–38	
15	above			0	11	0	1	10	296*y*	*y*	0	Included	above
16	58	8	6	0	52	0	52	0	*y*	*y*	0	35–36	0.087
17	1	0	0	0	0	0	0	0	*y*	*y*	0		
18	90	3	71	0	19	0	1	18	400	*y*	*y*	20–42	
19	8	1	*y*	0	*y*	1	*y*	*y*	*x*	*x*	0	*y*	
20	3	0	2	0	1	0	1	0	*x*	*x*		*x*	
21	7	6	0	0	5	2	7	0	*y*	*y*	0	56	
22	215	6	177	0	48	0	6	42	Variable		0	21–38	
23	187	10	1	0	64	0	18	46	*y*	*y*	0	19–33	
24	*y*	0	0	0	0	0	0	0	*x*	*x*	0	55	
25	2	1	1	0	1	0	1	0	*y*	*y*	0	35.6	
26	66	0	60	*y*	6	0	0	6	*x*	*y*	0	14–19	
27	1	0	0	0	1	0	0	0	100	*y*	0	23	
28	1	0	0	0	1	0	1	*y*	*y*	*y*	0	59	
29	3	1	0	0	3	0	3	0	1,045	*y*	*y*	38.7	
30	*y*	43	*y*	0	*y*	0	*y*	*y*	1,425	*y*	*y*	47	
31	1	0	0	0	1	0	*y*	*y*	1,140	*y*	*y*	45	
32	42	0	0	0	*y*	0	0	100	315	*y*	*y*	22	
33	1	0	0	0	*y*	0	*y*	*y*	1,475	*y*	0	29.6	
34	19	7	5	0	13	1	14	0	3,300	*y*	0	32.3	
35	18	0	2	0	16	0	16	0	2,750	*x*	0	29.6–36.2	
36													
37	2	2	0	0	2	0	2	0	*y*	*y*		37.7	
38	1*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*		35.5	
39	6	3	2	0	4	0	4	0	*x*	*x*		51	
40	3	0	*y*	*y*	*y*	*y*	*y*	*y*	1,500	*y*	0	*y*	*x*
41	18	0	4	0	14	0	13	1	2,500	*y*		22–34	
42	69	0	22	0	44	3	2	45	*x*	*y*		22–27	
43	75	1	31	0	42	2	44	0	650	*y*		26–31	
44	23	0	15	0	8	0	1	7	2,400	*x*		40	
45	7	*y*	*y*	0	4	3	5	2	4,800	*x*		22–48	
46	7	4	0	0	7	0	7	0	*y*	*y*		40–51.2	
47	50	17	28	0	15	7	*y*	*y*	*x*	*x*		*y*	
48	14	10	6	0	5	3	8	0	1,100	*x*		*y*	
49	3	2	1	0	2	0	2	0	*y*	*y*	0	54	*x*
50	989	1	57	0	929	3	883	49	2,275	*y*		35–40	
51	52	4	33	0	13	6	18	1	340	*x*		22	
52	0.74	0	21	0	53	3	32	16	1,050	*x*		30–42	
53							5	3				29.6	

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Eponides Yegua	Eoc	S	34	6,622	6,634	10	D	Cook Mt.	7,695
2									Miocene	5,958
3	Frio	Olig	S	Por	9,171	9,184	10	D	Frio	11,117
4	Frio	Olig	S	Por	6,778	6,791	10	D	Vicksburg	7,882
5	Marginulina and Frio	Olig	S	27	7,145	7,600	60	DF	Frio	8,749
6	Frio	Olig	S	Por	10,000	10,500	6	D	Frio	11,451
7	Marginulina and Frio	Olig	S	Por	6,544	7,461	20	Ny	Frio	8,889
8	Marginulina Frio	Olig	S	Por	6,614 11,345	6,624 11,349	4	N	Frio	7,531
9	Mio-Pli-Het. Frio	Pli, Mio, Olig	S	Por	3,000	4,700	50±	DS	Vicksburg	6,743
10	Frio	Olig	S	Por	11,631	11,651	4		Frio	11,860
11	Cockfield	Eoc	S	Por	6,170	6,211	10	DSF	Wilcox	10,574
12	Cap rock, Pli, Mio, Olig	Cap rock, Pli, Mio, Olig	S	Por	800	7,200	{ 80 100 }	DS	Jackson	8,150
13	Mio, Frio	Mio, Olig	S	30	3,450	6,690	{ 80 10 }	DS	Jackson	8,184
14	Cap rock, Olig, Yegua	Cap rock, Olig, Eoc	S L	Por Cav	245	6,525	y	DS	Cook Mt.	6,828
15	Mio	Mio	S	Por	4,900	5,600	30	DS	Cook Mt.	6,828
16	Olig, Marginulina, Frio	Olig	S	27	7,023	8,261	y	D	Vicksburg	11,465
17	Cockfield	Eoc	S	Por	4,825	4,832	7	F	Upper Saline Bayou	6,013
18	Pli, Mio, L. Olig	Pli, Mio, Olig	S	Por	800	4,528	21	DS	Cook Mt.	8,273
19	Pli, Mio	Pli, Mio	S	Por	{ 8,705 1,700	8,720 5,958	15 } 10–50 }	DS	Frio	8,720
20	Cap Rock, Mio	Cap rock, Mio	LS S	Cav Por	y	862	y	DS	x	4,435
21	Frio	Olig	S	Por	8,290	8,300	15	y	Frio	8,525
22	Mio, Frio	Mio, Olig	S	30	1,956	4,650	55	DS	Yegua	5,280
23	Cap rock, Olig, Frio	Cap rock, Olig	L S	Cav Por	377	5,615	15–60	DS	Vicksburg	6,281
24	Frio	Olig	S	Por	4,758	4,771	y	y	Vicksburg	6,510
25	Frio	Olig	S	Por	4,758	4,771	y	y	Frio	6,557
26	Mio	Mio	S	Por	190	1,500	10	DS	Wilcox	5,039
27	Frio	Olig	S	Por	2,966	2,976	16	D	Yegua y	7,200
28	Wilcox	Eoc	S	Por	7,225	7,230	5	y	Wilcox	10,998
20	L. Marginulina, Frio	Olig	S	Por	7,750	7,926	60	DF	Frio	10,570
30	Cockfield	Eoc	S	Por	3,617	3,674	12	DF	Cockfield	3,936
31	Frio	Olig	20		7,850	7,860	10	DF	Frio	9,582
32	Cockfield	Eoc	S	Por	3,021	3,039	15	DF	Saline Bayou	4,230
33	Cockfield	Eoc	S	Por	6,908	6,918	10	NF	Yegua	7,700
34	Mio, Olig, Discorbis	Mio, Olig	S	25	7,209	7,478	40	DS	Oligocene	8,805
35	Mio, Frio	Mio, Olig	S	35	4,400	6,050	25	D	Vicksburg	8,507
36										
37	Frio	Olig	S	Por	8,566	8,564–72	8	DF	Frio	9,564
38	Edwards	LCre	LS	Por	6,167	6,172	5	F	Edwards	6,172
39	L. Frio	Olig	S	Por	9,800	9,870	10	D	Frio	11,430
40	Oakville	Mio	S	Por	3,750	4,143	85	A	Frio	11,612
41	Mio	Mio	S	Por	2,387	5,960	15	DS	Frio	8,198
42	Mio, Cockfield, Wilcox	Mio, Eoc	SH	Por	1,124	1,500	120	DS	Wilcox	8,306
43	Frio	Olig	S	25	5,790	5,979	40	DF	Frio	7,210
44	U. Cockfield Wilcox	Eoc	S	15	5,672	9,100	8	D	Wilcox	10,075
45	Mio, Cockfield	Mio, Eoc	S	Por	3,207	8,102	20	D	Cook Mt.	8,763
46	Yegua	Eoc	S	Por	7,499	7,502	20	D	Yegua	8,090
47	Catahoula, Frio	Mio, Olig	S	Por	2,861	2,880	10	MF	Yegua?	7,860
48	Catahoula, Frio	Mio, Olig	S	Por	2,860	4,850	25+	NF	Vicksburg	5,168
49	Mio	Mio	S	Por	5,891	5,892	y	AF	Miocene	6,240
50	Cockfield, Yegua	Eoc	S	27	5,000	5,250	30	D	Wilcox	9,040
51	Mio, Catahoula	Mio	S	Por	2,654	2,753	15	DF	Vicksburg	5,177
52	L. Marginulina, Frio, Mar-	Olig	S	34	6,409	6,531 }	9	Dsf	{ Frio	7,007
53	ginulina, Frio	Olig	S	34	6,277	6,345 }			{ Vicksburg	8,850

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941
54	Damon Mound, *Brazoria*	1915	250	0	7,117,881	87,502	*y*	*y*
55	Danbury, *Brazoria*	1929	160	*y*	547,877	158,503	*y*	*y*
56	Diamond Half, *Goliad*	1936	240	0	76,619	33,009	*y*	*y*
57	Dickinson, *Galveston*	1934	2,700	*y*	6,932,505	697,507	*y*	*y*
58	Dinero, *Live Oak*	1935	350	*y*	81,773	648	*y*	*y*
59	Dirks, *Bee*	1934	865	0	5,957,691	426,437	*y*	*y*
60	Duck Bay, *Calhoun*	1940	*y*	*y*	7,000	*y*	*y*	*y*
61	Dyersdale, *Harris*	1940	1,000	*y*	361,458	318,364	*y*	*y*
62	East Bernard, *Wharton*	1940	100	*y*	600	Gas dist.	*y*	*y*
63	East Placedo, *Victoria*	1937	300	0	377,619	*y*	*y*	*y*
64	Edna, *Jackson*	1937	420	*y*	4,685	*y*	*y*	*y*
65	Edwards Ranch, *Victoria*	1940	*y*	*y*	*y*	*y*	Shut in	
66	Esperson, *Liberty*	1929	700	0	6,559,254	602,700		
67	Esperson, South, *Liberty*	1939	550	0	855,863	340,758	*y*	*y*
68	Eureka, *Harris*	1934	850	*y*	2,852,403	588,442		
69	Eureka Heights, *Harris*	1935	50	*y*	40,793	3,810	*y*	*y*
70	Fagan, *Refugio*	1940	*y*	*y*	143,294	123,284	*y*	*y*
71	Fairbanks, *Harris*	1939	4,000	*y*	8,780,253	2,813,256	*y*	*y*
72	Fannette, *Jefferson*	1926	500	0	3,047,614	442,969	*y*	*y*
73	Deep	1940	?	20				
74	Fannin, *Goliad*	1939	*y*	80	*y*	*y*	*y*	*y*
75	Fig Ridge, *Chambers*	1940	900	*y*	51,918	41,918	*y*	*y*
76	Fishers Reef, *Chambers*	1940	100	*y*	29,260	27,760	*y*	*y*
77	Fort Merrill, *Live Oak*	1935	20	0	32,000	*y*	*y*	0
78	Fostoria, *Montgomery*	1941	40	*y*	*y*	*y*	*y*	*y*
79	Francitas, *Jackson*	1937	420	*y*	268,049	102,918	*y*	*y*
80	Fred, *Tyler*	1941	160	*y*	5,172	5,172	*y*	*y*
81	Ganado, *Jackson*	1937	120	*y*	188,795	76,565	*y*	
82	Garwood, *Colorado*	1933	275	0	50,681	44,442	*y*	*y*
83	Genevieve, *Bee*	1941	20*y*	*y*	1,249	1,249	*y*	*y*
84	George West, *Live Oak*	1940	*y*	20	*y*	*y*		
85	Gillock, *Galveston*	1936	2,200	*y*	6,533,910	1,268,910	*y*	*y*
86	Goodrich, *Polk*	1941	40	*y*	4,197	4,197	*y*	*y*
87	Goose Creek, *Harris*	1912	900	*y*	72,369,115	513,693	*y*	*y*
88	Greens Lake, *Galveston*	1936	225	*y*	88,168	33,774	*y*	*y*
89	Greta, *Refugio*	1933	4,240	*y*	32,020,968	2,329,588	*y*	*y*
90	Halls Bayou, *Galveston*	1941	20	*y*	*y*	*y*	*y*	*y*
91	Hamman, *Matagorda*	1936	1,100	*y*	3,101,229	614,969	*y*	*y*
92	Hankamer, *Liberty*	1929	250	*y*	5,542,475	170,292	*y*	*y*
93	Hankamer (New), *Liberty*	1934	150		679,532	69,566		
94	Hardin, *Liberty*	1935	2,750	*y*	7,489,033	1,612,251	*y*	*y*
95	Hartzendorf, *Bee*	1935	*y*	*y*	*y*	*y*	*y*	*y*
96	Hastings, *Brazoria*	1934	5,800	*y*	35,272,599	7,625,599	*y*	*y*
97	Hawkinsville, *Matagorda*	1936	*y*	*y*	2,000	0	0	0
98	Heyser, *Calhoun*	1936	?	3,620	14,197,601	2,642,601	*y*	*y*
99	High Island, *Galveston*	1922	320	*y*	17,830,098	989,239	*y*	*y*
100	Hillje, *Wharton*	1939	750	*y*	307,583	229,344	*y*	*y*
101	Hitchcock, *Galveston*	1936	200	*y*	872,735	152,146	*y*	*y*
102	Hockley, *Harris*	1932	10	*y*	16,000	0	*y*	*y*
103	Holzmark, *Bee*	1935	20	*y*	10,812	8,783	*y*	*y*
104	Hordes Greek, *Goliad*	1935	80	*y*	62,047	8,264	*y*	*y*
105	Hoskins Mound, *Brazoria*	1906	10	0	31,755	0	*x*	*x*
106	Hull, *Liberty*, 500–4400 ft	1918	850	0	93,909,101	2,377,092	*y*	*y*
107	4650–5161 ft	1932		Included above			*y*	*y*
108	Humble, *Harris*, 700 ft	1905	2,300	0	126,760,241	916,563	*y*	*y*
109	5670 ft	1928		Included above		*y*	*y*	*y*
110	Joes Lake, *Tyler*	1937	2,350	*y*	2,482,626	886,972	*y*	*y*
111	Joyce Richardson, *Harris*	1940	150	*y*	47,297	32,297	*y*	*y*

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
54	131	2	101	0	30	0	0	30	x	y		21-33	
55	21	2	7	0	14	0	4	10	500	y		22-28	
56	y	y	y	y	y	y	y	y	x	y		47	
57	261	6	175	0	72	14	72	14	1,250	y		37.5	
58	y	y	y	y	1	0	0	1	1,600	y		43	
59	101y	y	y	y	y	y	y	y	1,000			44	
60	7	5	y	0	2	0	y	y	y	y		37.6-36.8	
61	45	37	3	0	41	1	38	4	y	y		22.3	
62	1	y	y	y	y	y	0	0				55	
63	y	2	y	y	2	0	y	y	1,080			38.5	
64	x	y	y	0	y	y	y	y	x	x		y	
65	2	y	y	y	y	2	2	0	x	x		y	
66	103	12	3	24	75	4	18	38	100y			30-41	0.02
67							23	0				21-35	
68	42	1	15	0	27	0	20	6	3,456	2,676		37-51	
69							1	0				y	
70	6	1	4	0	1	1	2	0				27.6-40.6	
71	309	6	15	0	280	13	291	2	3,000	y		38.8	
72	54	22	15	0	37	1	26	13	540	y		26-38	
73	12		Included above			1	above					26-38	
74	1	y		y	y	y	y	y	x	y		x	
75	7	3	0	0	7	0	7	0	y	y		32	
76	3	2	1	0	2	0	2	0	y	y	0	32.6	
77	2	y	y	y	y	y	y	y	1,100	0	0		
78	y	1	y	0	1	0	1	0	y	y	y	39.0	
79	14	6	8	0	5	0	5	0	2,450		0	48	
80	1	1	0	0	1	0	1	0	y	x	0	39.6	
81	19	8	11	0	7	1	8	0	2,252		0	26	
82	11y	7	7y	0	4	0	4	0	1,225	x	0	44	
83	1	1	1	0	1	0	1	0	y		0	54	
84	1	y									0		
85	98	3	1	0	97	0	88	9	1,250		0	37.5	
86	1	1	0	0	1	0	1	0	y		0	32.2	
87	914	8	827	0	87	y	1	86	y	y	0	20-36	
88	11	5	8	0	2	1	3	0	1,300	y	0	22-52	0.14
89	300	1	285	0	1	14	15	0	1,350	y	0	23.2-34.9	
90	1	1	0	1	0	0	0	0	y	y		47.5	
91	43	3	19	0	24	0	10	14	800	y	0	37	
92	50	0	13	0	29	y	4	25	424	y	0	18-32	
93					8	y	5	3				25-32	
94	175	6	25	0	150	0	117	33	900	y	0	37-56	
95	1	y		y	y	y	y	y	0	0	0	45	
96	693	5	1	0	692	0	673	19	2,740	y	0	30-33	
97	1	0	1	0	0	0	0	0	200	0	0	y	
98	277	13	y	y	11	2	y	y	880	y	0	32.3	
99	139	2	80	0	59	0	22	37	y	y	0	31.5	
100	18	4	4	0	13	1	12	2	y	y	0	25	
101	14	0	0	0	14	y	10	4	880	y	0	29-31	
102	4	0	4	0	0	y	y	y	40	y	0	22	
103	6	0	y	y	y	y	y	y	1,050	x	0	44.3	
104	5	2	y	y	y	1	y	y	1,550	x	0	47.6	
105	5	0	5	0	0	x	0	0	x	x	0	21.5	
106	822	26	633	0	189	0	18	171	x	x	0	17-39	
107			Included above						x	x	0	above	
108	1,810	17	1,558	0	252	0	13	239	y	y	0	17-45	
109			Included above						y	y	0	above	
110	46	4	0	0	46	0	46	0	1,425	1,400	0	40-47	
111	7	1	4	0	2	1	3	0	y	y	0	42-58	

TABLE I.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
54	Pli, Mio, Olig	Pli, Mio, Olig	SH	Por	1,406	3,800	43	DS	Olig	8,112
55	Mio, Frio	Mio, Olig	S	Por	1,559	7,168	12	DS	Frio	8,058
56	Cockfield	Eoc	S	Por	3,682	3,880	14	DF	*y*	*y*
57	Frio	Olig	S	Por	7,800	9,142	20	DF	Frio	9,463
58	Yegua	Eoc	S	Por	5,200	5,220	7	D	Cook Mt.	5,913
59	Cockfield	Eoc	S	Por	3,819	3,990	16	DF	Yegua	4,776
60	Mio	Mio	S	Por	5,654	5,661	1	?	Frio	10,002
61	Frio	Olig	S	Por	4,050	4,083	10	DF	Yegua	8,515
62	Cook Mt.	Eoc	S	Por	8,070	8,090	20	?	Cook Mt.	8,461
63	Frio	Olig	Sh	Por	6,370	6,382	15	AF	Vicksburg	7,502
64	Catahoula, Frio	Olig, Mio	S	Por	2,646 3,890	2,830 5,350	10	D	Cock	7,180
65	Frio	Olig	S	Por	5,030	5,041	5	?	Vicksburg	6,265
66	{ Mio, Jackson	Mio, Eoc	S	Por	2,275	8,314 }	15	DF	{ Cook Mt.	9,734
67	{ Yegua-Cook Mt.	Eoc	S	Por	7,341	8,900 }			{ Cook Mt.	9,375
68	Cockfield	Eoc	S	Por	7,662	8,094 }	25	A	{ Yegua	9,038
69	Yegua	Eoc	S	Por	7,662	8,094 }			{ Yegua	9,038
70	Frio	Olig	S	Por	2,108	5,898	12	?	Frio	6,715
71	Yegua	Eoc	S	Por	6,505	7,185	20	AF AC	Yegua	7,940
72	Mio, Olig	Mio, Olig	S	Por	3,250		20	DS	Frio	*y*
73	Frio	Olig	S	Por		8,300	*y*	DS	Frio	10,595
74	Catahoula	Mio	S	Por	2,855	2,860	5	A	Frio	3,512
75	Frio	Olig	S	Por		8,807	4	D	Frio	8,865
76	Frio	Olig	S	Por	8,962	8,964	2	D	Frio	9,952
77	Yegua	Eoc	S	Por	4,643	4,706	5	D	L. Saline Bayou	5,124
78	Cockfield	Eoc	S	Por	5,790	5,794	4	*y*	Wilcox	11,794
79	Frio	Olig	S	Por	7,380	7,950	15	A	Frio	9,030
80	Wilcox	Eoc	S	Por	8,180	8,200	15	AF	Wilcox	8,500
81	Marginulina	Olig	S	Por	5,102	5,111	5	D	Frio	6,544
82	Frio, Cockfield	Olig, Eoc	S	12.8	4,021	6,203	12	D	Wilcox	10,536
83	Cockfield	Eoc	S	Por	4,160	4,178	18	AF	Cockfield	4,187
84	Wilcox	Eoc	S	Por	8,340	8,346	6	?	Wilcox	8,386
85	Frio	Olig	S	Por	8,300	8,800	12	DF	Frio	9,463
86	Cockfield	Eoc	S	Por	4,030	4,034	4	DF	Wilcox	9,966
87	Pli, Mio, Olig	Pli, Mio, Olig	S	Por	1,000	5,894	40	D	McElroy	6,967
88	Pli, Mio	Pli, Mio	S	20–25	2,712	6,450	10	DS	Mid, Olig	9,636
89	Catahoula, Heterostegina, Frio	Mio, Olig	S	20–33	2,000	3,500	20	A	Vicksburg	7,473
90	Frio	Olig	S	Por	10,175	10,180	5		Frio	10,412
91	Frio	Olig	S	Por	8,182	9,370	10	DS	Frio	11,465
92	Mio, Marginulina, Frio	Mio, Olig	S	20*y*	2,561	5,162	29	DS	Yegua	7,681
93	Mio	Mio	S	*y*	2,407	5,715	29	DS	Vicksburg	7,891
94	Yegua	Eoc	S	27–31	7,547	7,673	10	D	Yegua	8,110
95	Cockfield	Eoc	S	Por	3,642	3,651	9	A	Yegua	3,907
96	L. Marginulina, Frio	Olig	S	30	5,157	6,140	200	DF	Vicksburg	8,793
97	Miocene	Mio	S	Por	5,150	6,300	10	DS	Olig	6,905
98	Mio, Frio	Mio, Olig	S	25	3,400	6,000	25	D	Frio	6,487
99	Cap rock, Mio	Cap rock, Mio	S	Por	1,500	6,710	40	DS	Olig	7,179
100	Frio	Olig	S	Por	5,220	5,234	10	D	Frio	7,004
101	Mio	Mio	S	Por	5,134	5,160	12	D	Frio	10,460
102	Cap rock, Frio	Cap rock, Olig	L S	Cav Por	1,800	2,400	30	DS	Cockfield	7,510
103	Text. hockleyensis	Eoc	S	Por	4,065	4,260	*y*	NF	Cockfield	4,458
104	Yegua	Eoc	S	Por		4,575	10	MF	Cook Mt.	6,004
105	*x*	*x*	SH	Por	600	623	23	DS	Miocene	4,126
106	Cap rock, Mio, Olig, Jackson	Cap rock, Mio	S	Por	400	5,228	63	DS	Cook Mt.	*y*
107	Claiborne, Yegua	Olig, Eoc	S	Por			*y*	DS	Cook Mt.	9,658
108	Cap rock, Mio, Olig, Jackson	Cap rock, Mio	A S	Cav Por	700	5,670	40	DS	*y*	*y*
109	Claiborne	Olig, Eoc	S	Por			200	DS	Cook Mt.	8,181
110	Wilcox	Eoc	S	Por	7,600	7,736	30	DF	Wilcox	9,014
111	Cockfield	Eoc	S	Por	6,654	6,926	7	D	Cockfield	7,250

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941
112	Katy, *Waller*	1935	0	12,000	155,464	Gas dist.	*y*	*y*
113	Keeran, *Victoria*	1932	640	640	1,518,927	165,485	*y*	*y*
114	Kubela, *Wharton*	1935	650		1,128,516	264,134	*x*	*y*
115	Labelle, *Jefferson*	1937	900	*y*	494,627	63,246	*y*	*y*
116	Lake Creek, *Montgomery*	1941	1,000	*y*	43,861	43,861	*y*	*y*
117	Lake View, *Wharton*	1941	*y*	*y*		Gas	*y*	*y*
118	Lamar, *Aransas*	1937	20	0		1,095	*y*	*y*
119	La Rosa, *Refugio*	1938	1,720	*y*	3,296,770	967,848	*y*	*y*
120	League City, *Galveston*	1938	740	*y*	1,724,238	622,146	*y*	*y*
121	Lissie, *Wharton*	1940	500	*y*	Shut in		0	0
122	Livingston, *Polk*	1933	1,800	*y*	6,776,690	573,505	*y*	*y*
123	Lockridge, *Brazoria*	1936	1,800	1,600	3,224,024	721,970	*y*	*y*
124	Lolita, *Jackson*	1940	*y*	*y*	1,639,737	1,421,774	*y*	0
125	Lost Lake, *Chambers*	1929	50	*y*	1,014,672	24,750	*y*	*y*
126	Louise, *Wharton*	1933	1,600	*y*	3,421,623	420,058	*y*	*y*
127	Lovell's Lake, *Jefferson*	1938	2,500	*y*	2,508,206	1,330,206	*y*	*y*
128	Lucas, Mount, *Live Oak*	1923	120	*y*	318,524	16,422	*y*	*y*
129	Lucky, *Matagorda*	1941	450	*y*	16,948	16,948	*y*	*y*
130	Magnet, *Wharton*	1936	1,500	*y*	2,122,939	776,938	*y*	*y*
131	Magnolia, *Montgomery*	1941	160	*y*	1,479	1,479	*y*	*y*
132	Manual, *Brazoria*, 4016 ft	1931	1,800	*y*	21,264,094	1,916,787	*y*	*y*
133	5100 ft	1931						
134	Markham, *Matagorda*	1908	230	*y*	8,387,816	273,990	*y*	*y*
135	Mathis, *Live Oak, San Patricio*	1924	120	*y*		Gas	*x*	*x*
136	Martha, *Liberty*	1939	500	*y*	267,235	155,373	*y*	*y*
137	Maurbro (Laward), *Jackson*	1941	*y*	*y*	183,233	183,233	*y*	*y*
138	Mauritz, *Jackson*	1935	*y*	*y*	506,720	104,731	*y*	*y*
139	McFaddin, *Victoria*	1932	620	*y*	2,671,350	690,568	*y*	*y*
140	McMurray, *Bee*	1937	*y*	*y*	Included with Pettus			
141	McNeil, *Live Oak*	1934	70	*y*	275,847	13,046	*y*	*y*
142	Melon Creek, *Refugio*	1939	210	*y*	410,503	149,833	*y*	*y*
143	Mineral, *Bee*	1937	*y*	*y*				
144	Moss Bluff, *Liberty*	1930	10	0	179,235	0	*x*	*x*
145	Mountain View, *Live Oak*	1939	*x*	20		Gas	*y*	*y*
146	Mount Houston, *Harris*	1940		Included in Dyersdale				
147	Mykawa, *Harris*, 4100–4900 ft	1929	180	0	928,783	41,999	*y*	*y*
148	4400–4600 ft	1930	150	0	3,509,313	212,956	*y*	*y*
149	Mission River, *Refugio*	1938			555,742	310,314	*y*	*y*
150	Nash, *Fort Bend*	1926			1,724,859		*x*	*x*
151	Navidad, *Jackson*	1941	*y*	*y*		Gas	*y*	*y*
152	Needville, *Fort Bend*	1941	0	40	*y*	*y*	*y*	*y*
153	Nome, *Jefferson*	1936	750	*y*	2,396,797	558,183	*y*	*y*
154	Normana, *Bee*	1930	70	10	91,276	7,245	*x*	*x*
155	North Dayton, *Liberty*, 1200 ft	1905	50	*y*	2,168,905	5,772	*y*	*y*
156	4800 ft	1927		Included with above				
157	North Houston, *Harris*	1938	1,000	*y*	189,439	54,488	*y*	*y*
158	North Kearan, *Victoria*	1940	20	*y*	5,429	*y*	*y*	*y*
159	North Laward, *Jackson*	1941	1,000	*y*	*y*	*y*	*y*	*y*
160	North Markham, *Matagorda*	1938	1,100	*y*	275,670	194,995	*y*	*y*
161	North Normana, *Bee*	1938	10	0	766	*y*	*y*	*y*
162	Oakville, *Live Oak*	1936	150	290	584,130	247,203	*y*	*y*
163	O'Connor, *Refugio*	1931	140	250	575,617	39,398	*y*	*y*
164	Old Ocean, *Brazoria*	1934	10,000	*y*	14,665,840	4,799,840	*y*	*y*
165	Orchard, *Fort Bend*	1926	150	50	3,853,422	52,076	*y*	*y*
166	Orange, *Orange*	1913	400	0	31,953,934	148,293	*x*	*x*
167	Oyster Bayou, *Chambers*	1941	1,000	*y*	42,041	42,041	*y*	*y*

TABLE I.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
112	12*y*	1	0	0	12	1*y*	13	0	*y*	*y*	0	*y*	
113	34	0	*y*	*y*	*y*	2	*y*	*y*	1,450	*y*	0	36	
114	21	1	0	0	20	1	0	21	*y*	*x*		*y*	
115	8	2	4	0	4	0	3	1	7,000	*y*	0	37.2	0.06
116	3	2	0	0	3	0	3	0	*y*	*y*	0	61	
117	1	1	0	0	0	1	1	0	*y*	*y*	0	Gas	
118	1	*y*	0	0	0	1*y*	1	0	*y*	*y*	0	*y*	
119	98	4	*y*	0	*y*	4	*y*	*y*	850 1,775	*y* *y*	0	39	
120	37	8	5	0	32	0	32	0	1,100 2,100	*x* *x*	0	40.5	
121	1	0	0	1	0	0	0	0	*y*	*y*	0	58	
122	98	0	20	0	78	*x*	11	67	700	*y*	0	40	
123	47	3	6	0	41	0	30	11	2,100	*x*	0	26	
124	176	117	60	0	116	0	116	*x*	*y*	*y*	0	31.1–37.1	
125	13	0	5	0	7*y*	1*y*	0	8	*x*	*x*	0	22.4	
126	51	1	15	0	32	4	13	23	1,850–1,300		0	26–38	
127	90	18	12	0	77	1	78	0	1,850	1,300	0	26	
128	41*y*	0	*y*	*y*	*y*	*y*	*y*	*y*	874 1,400	*y*	0	36	
129	2	1	0	0	2	0	2	0	*y*	*y*	0	39	
130	82	14	8	0	74	0	74	0	*y*	*y*	0	25.4	
131	1	1	0	0	1	0	1	0	*y*	*y*	0	57.7	*y*
132	195*y*	3	17	0	174	4	106	72	*x*	*x*	0	24	*y*
133									*x*	*x*		26	
134	165	10	124	0	41	*x*	9	32	*x*		0	25–40	
135	4	*y*	*y*	*y*	*y*	*y*	*y*	*y*	935	*x*	0	*x*	
136	12	5	0	0	12	0	11	1	3,509	*x*	0	41	*x*
137	10	10	0	0	10	0	10	0	*y*	*y*	0	24.4	
138	4	*y*	*y*	*y*	*y*	*y*	*y*	*y*	2,467		0	31	0.11
139	93	17	72	0	14	7	18	3	1,185 1,725	*x*	0	21.2	
140			Included with Pettus						570		0	47	
141	7*y*	*y*	*y*	*y*	*y*	*x*	*y*	*y*	1,150	*x*	0	44.3	
142	10*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*		0	35.5	
143	12	*y*	*y*	*y*	*y*	*y*	*y*	*y*	100	*x*	0	45	
144	5	0	0	0	0	0	0	0	280	0	0	0	0
145	1	*y*	*y*	*y*	*y*	*y*	11	*y*			0	*x*	*y*
146													
147	45	0	16	0	9	*x*	0	9	290	*x*	0	27.5	
148				0	20	0	20	0			0	27.5	
149	7	0	0	0	0	*y*	0	0	590 1,100	*y* *y*	0	42.6	
150	24	0					0	0	800	0	0	0	
151	2	2	*y*	0	0	2	2	0	*y*	*y*	0	Gas	
152	1	1	0	0	0	1	0	0	*y*	*y*	0	*y*	*y*
153	44	0	3	0	41	*y*	32	9	2,550	*y*	0	26.9	0.25
154	7	0	*y*	0	*y*	*y*	*y*	*y*	150	*y*	0	38.8	*y*
155	64	1	61	0	3	*y*	0	3	*x*	*y*	0	22–33	*y*
156									400	*y*	0	Included in above	
157	5*y*	0	0*y*	0	5	*y*	5	0	*y*	*y*	0	*y*	*y*
158	5	4	2	0	2	1	3	0	*y*	*y*	0	*y*	*y*
159	12	12	1	0	11	*y*	11	0	*y*	*y*	0	25.8	*y*
160	19	13	0	0	19	*y*	19	0	3,450	*y*	0	36	*y*
161	1	0	0	0	1	*y*	*y*	1	*y*	*y*	0	46.5	*y*
162	34	8	30	0	4	*y*	*y*	4	1,300	*y*	0	23	*y*
163	10	0	*y*	0	*y*	6	6*y*	*y*	365	*y*	0	22.6	*y*
164	115	40	8	0	107	*y*	105	2	4,700	*y*	0	52–68	*y*
165	35	0	26	0	9	*y*	3	6	375	*y*	0	22–51.5	*y*
166	328	4	292	0	36	*y*	0	36	*x*	*y*	0	20–42	*y*
167	6	3	0	0	6	*y*	6	0	*y*	*y*	0	35.9	*y*

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
112	Yegua	Eoc	SH	27 10.2	6,400	7,800	100	A	Wilcox	11,078
113	Frio	Olig	S	15	5,597	7,071	10	MF	Vicksburg	10,043
114	Frio	Olig	S	Por	4,596	4,790	y	DS	y	y
115	Marginulina	Olig	S	30	8,260	8,670	11	Ds	Frio	10,147
116	Wilcox	Eoc	S	2	9,200	9,800	50	F?	Wilcox	13,330
117	Miocene	Mio	S	Por	3,400	3,411	10	?	Frio	7,607
118	Frio	Olig	S	Por	7,502	7,997	y	y	Frio	9,785
119	Frio	Olig	S	30	5,382	6,385	20±	DFV	Frio	7,021
120	Frio	Olig	S	30	8,695	10,960	20	D	Vicksburg?	11,402
121	Yegua	Eoc	S	Por	6,728	6,734	6	y	Wilcox	10,116
122	Conroe-Jackson	Eoc	S	Por	3,285	4,360	20	DF	Cockfield	5,596
123	Frio	Olig	S	20	6,309	6,387	20	AF	Vicksburg	9,684
124	Frio	Olig	S	32	5,274	6,398	4	D	Frio	7,280
125	Marginulina, Frio	Olig	S	Por	2,679	5,157	33	DS	Frio	7,471
126	Marginulina, Frio	Olig	S	Por	5,135	7,143	15	D	Vicksburg	8,271
127	Frio	Olig	S	30	7,713	7,792	22	DS	Frio	8,189
128	Catahoula, Frio, Yegua	Mio, Olig, Eoc	S-Sh	Por	1,750	5,300	28	D	Cook Mt.	6,789
129	Frio	Olig	S	Por	8,883	8,886	3	D	Frio	10,500
130	Marginulina	Olig	S	Por	5,490	5,560	20	D	Frio	6,518
131	Wilcox	Eoc	S	Por	8,448	8,458	10	DF	Wilcox	10,008
132	Miocene	Mio	Sh	27.9	3,990	4,016	23	D	y	y
133	Marginulina	Olig	S	22.5	5,000	5,500	26	D	Vicksburg	7,957
134	Cap rock, Pli, Mio, Olig	Cap rock, Pli, Mio	L SH	Cav, Por	936	4,350	20	Ds	Vicksburg	6,436
135	Catahoula	Olig, Mio	S	Por	2,375	2,385	10	ML	McElroy	5,526
136	Yegua	Eoc	S	30	8,100	8,108	5	AF	Yegua	9,109
137	Marginulina, Frio	Olig	S	Por	5,220	5,230	10	AF	Frio	6,520
138	Frio	Olig	S	Por	5,640	5,650	8	ML	Frio	7,408
139	Catahoula, Heterostegina, Frio	Mio, Olig	S	Por	2,440 4,400	2,470 5,300	24 10	AF	Frio	7,025
140	Yegua	Eoc	S	Por	4,267	4,284	8	NF	Yegua	4,379
141	Hockleyensis, Cockfield	Eoc	S	Por	4,434	4,992	10	D	Cook Mt.	6,212
142	Frio	Olig	S	Por	5,856	5,876	20	A	Frio	5,876
143	Cockfield	Eoc	S	Por	3,545	3,650	8	NF	Cockfield	4,536
144	Cap rock, Marginulina	Pre Tert, Olig	SH	Cav, Por	800	5,800	33	Ds	Vicksburg	7,375
145	Text. hockleyensis	Eoc	S	Por	2,476	2,481	10	F	Cock	3,000
146										
147	Mio, Heterostegina	Mio, Olig	SH	Por	4,100	4,300	30	D		
148	Frio	Olig	SH	Por	4,400	4,892	30	D	U. Saline Bayou	7,178
149	Frio	Olig	S	Por	5,445	7,150	15±	D	Vicksburg	9,225
150	Miocene, Oligocene	Mio, Olig	S	Por	3,700	5,677	60y	Ds	Vicksburg	6,800
151	Mio	Mio	S	Por	3,788	3,796	8	DF	Vicksburg	7,553
152	Frio	Olig	S	Por	5,176	5,180	8	Df	Vicksburg	7,025
153	Marginulina	Olig	S	Por	4,775	6,060	12	Ds	Vicksburg	9,045
154	Hockleyensis	Eoc	Sh	Por	3,500	3,676	17	D	Yegua	5,038
155	Cap rock, Mio, Olig	Cap rock, Mio, Olig	Cav, S	LS Por	400	5,188	x	Ds	Oligocene	5,700
156	Included above						32	Ds		
157	Yegua	Eoc	S	Por	y	y	y	Df	y	y
158	Frio	Olig	S	Por	5,550	5,552	2	?	Vicksburg	7,509
159	Frio......................	Olig	S	Por	5,207	5,226	10	?	Vicksburg	7,506
160	Frio	Olig	S	Por	7,702	7,770	20	Df	Frio	8,503
161	Cockfield	Eoc	Sh	Por	4,218	4,258	5	Mf	Cockfield	4,273
162	Mio, Olig, Jackson-Cockfield	Mio, Olig, Eoc	S	Por	265	2,816	8	Af	Cook Mt.	4,500
163	Mio	Mio	S	Por	2,136	4,150	8	Af	Frio	6,860
164	Frio	Olig	S	27	8,636	10,670	200	D	Frio	11,357
165	Cap rock, Mio, Olig, Yegua	Cap rock, Mio, Olig	Cav, S	LS 20	1,265	7,975	25	Ds	Cook Mt.	10,085
166	Pli, Mio, Olig	Pli, Mio, Olig	S	Por	2,500	6,123	30x	Ds	Frio	7,604
167	Frio	Olig	S	Por	8,250	8,280	20y	Ds	Frio	8,835

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941
168	Palacios, *Matagorda*	1937	300	*y*	131,231	4,265	*y*	*y*
169	Pettus, *Bee*	1930	1,180	1,220	8,983,323	122,825	*y*	*y*
170	Pettus (New), *Bee, Goliad, Karnes*	1930	950	50	436,431	206,390	*y*	*y*
171	Picketts Ridge and Kubela, *Wharton*	1935	1,200	*y*	4,008,367	777,104	*y*	*y*
172	Pierce Junction, *Harris*	1921	340	0	34,019,962	633,806	*y*	*y*
173	Placedo, *Victoria*	1935	1,920	*y*	13,173,072	1,287,072	*y*	*y*
174	Pledger, *Brazoria*	1932	*y*	*y*	17,000	Gas	*y*	*y*
175	Plumber, *Bee*	1936	160	220	260,739	21,852	*y*	*y*
176	Port Lavaca, *Calhoun*	1934	220	220	420,856	*y*	*y*	*y*
177	Port Neches, 3150 ft., *Orange*	1928	640	*y*	5,731,192	151,638	*y*	*y*
178	West Port Neches, 5944 ft., *Orange*	1936	Above		260,171	260,171	*y*	*y*
179	Powderhorn Lake, *Calhoun*	1939	*y*	*y*	0	Gas	*y*	*y*
180	Raccoon Bend, *Austin*, 3490 ft.	1927	1,624	*y*	23,841,604	1,333,081	*y*	*y*
181	4120 ft.	1934	1,470	600	Included above		*y*	*y*
182	Ray, *Bee*	1934	420	*y*	1,567,576	61,813	*y*	*y*
183	Refugio, *Refugio*, deep	1920	Below		17,715,258	1,104,817	*y*	*y*
184	Shallow	1928	3,820	6,450	21,979,442	359,538	*y*	*y*
185	Refugio Fax, *Refugio*	1940	150	*y*	297,878	164,851	*y*	*y*
186	Rockland, *Jasper*	1929	20	*y*	42,324	2,496	*x*	*y*
187	Rosslyn, *Harris*	1938	100	0	42,343	5,785	*y*	*y*
188	Rosenberg, *Fort Bend*	1939	200	*y*	15,492	Shut in	*y*	*y*
189	Rowan, *Brazoria*	1940	460	*y*	190,646	145,416	*y*	*y*
190	Sabine Pass, *Jefferson*	1941	50	*y*	10,883	10,883	*y*	*y*
191	Sandy Point, *Brazoria*	1937	80	*y*	277,074	33,068	*y*	*y*
192	Saratoga, *Hardin*	1901	500	*y*	29,760,011	287,303	*y*	*y*
193	Sarco, *Goliad*	1938	40	*y*	2,234	533	*x*	*y*
194	Satsuma, *Harris*	1936	500	*y*	588,556	88,923	*x*	*y*
195	Schwab, *Polk*, Shallow	1934	200	*y*	150,238	2,283	0	0
196	Wilcox	1939	200	*y*	264,744	73,818	0	0
197	Seabreeze, *Chambers*	1936	600	0	475,888	119,566	*y*	*y*
198	Segno, *Polk*, Shallow	1936	425	*y*	2,465,846	323,986	*y*	*y*
199	Deep	1938	2,100	*y*	2,801,571	1,203,491	*y*	*y*
200	Shepherd, *San Jacinto*	1940	*y*	*y*	2,330	*y*	*y*	*y*
201	Sheridan, *Colorado*	1940	675	*y*	79,195	48,302	*y*	*y*
202	Silsbee, *Hardin*	1936	1,000	*y*	2,674,198	695,355	*y*	*y*
203	Slick, *Goliad-Dewitt*	1930	80	240	75,812	939	*y*	*y*
204	Smith Point, *Chambers*	1940	900	*y*	157,064	150,114	*y*	*y*
205	Sour Lake, *Hardin*	1902	900	*y*	79,410,239	381,802	*y*	*y*
206	South China, *Jefferson*	1939	250	*y*	299,315	174,969	*y*	*y*
207	South Houston, *Harris*	1935	620	*y*	6,768,502	788,403	*y*	*y*
208	South Liberty, *Liberty*	1925	250	*y*	15,297,174	150,569	*y*	*y*
209	South White Creek, *Live Oak*	1941	*y*	*y*	5,012	5,012	0	0
210	Spanish Camp, *Wharton*	1936	*y*	*y*	*y*	Gas	*x*	*y*
211	Spindletop, *Jefferson*	1901	400	*y*	125,892,424	487,956	*x*	*x*
212	Splendora, *Montgomery*	1934	100	*y*	1,000	*y*	*y*	*y*
213	Stratton Ridge, *Brazoria*	1932	25	*y*	60,748	30,374	*y*	
214	St. Charles, *Aransas*	1940	20	*y*	19,199*y*	19,199*y*	*y*	*y*
215	Steamboat Pass, *Calhoun*	1941	*y*	*y*	*y*	*y*	0	*y*
216	Stowell, *Jefferson*	1941	475	*y*	2,667	2,667	*y*	*y*
217	Sugarland, *Fort Bend*	1928	1,200	*y*	30,629,243	646,242	*y*	*y*
218	Telferner, *Victoria*	1937	30	30	10,288	5,638	*y*	*y*
219	Texana, *Jackson*	1940	100*y*	*y*	15,207	8,099	*y*	*y*
220	Thomaston, *Dewitt*	1939	40	*y*	7,780	5,280	*y*	*y*
221	Thompson, *Fort Bend*	1940	6,515	*y*	43,408,233	4,585,483	*y*	*y*
222	Thompson (Vicksburg), *Ft. Bend*	1931			Included with above			
223	Toland, *Refugio*	1939	*y*	40	5,392	*y*	*y*	*y*
224	Terrell, *Victoria*	1940	*y*	*y*	8,937	7,212	*y*	*y*
225	Tomball, *Harris*	1933	8,900	*y*	20,015,743	3,282,743	*y*	*y*
226	Tom O'Connor, *Refugio*	1934	8,920	0	26,809,760	5,645,373	*y*	*y*

TABLE I.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
168	9	5	2	0	7	y	1	6	x	y	0	54	y
169	89	1	88	0	1	y	1	0	236	y	0	45	y
170				Included above						y	0	47.5	y
171	77	1	31	0	46	y	33	13	2,053	y	0	25–26	y
172	270	6	206	y	64	y	15	49	355	y	0	21–41	y
173	179	0	y	y	y	y	y	y	1,900	y	0	25	y
174	12	0	y	y	y	y	0	0	2,450	y	0	55.8	y
175	y	0	y	y	y	y	y	y	1,010	y	0	25	y
176	13	0	y	y	y	y	y	y	x	y	0	61	y
177	46	5	5	y	15	y	3	12	x	y	0	25	y
178	Above	7	Above		26	y	21	5	y	y	0	38	y
179	1	y	y	y	y	1	y	1	1,850	y	0	54	y
180	250	0	18	y	67	y	67	y	275	y	0	26–33.5	y
181					Included above				1,800	y	0	Included above	
182	11	0	y	y	y	y	y	y	1,755	y	0	46	y
183	Below	0	y	y	y	y	y	y	550 2,000	y	0	33	y
184	506	0	y	y	y	y	y	y	1,500 ±	y	0	39	y
185	15	15	3	y	12	y	12	0	700 200	y	0	38–42	y
186	10	0	9	y	1	y	0	1	x	y	0	21–35	y
187	1	0	0	y	1	y	1	0	1,800	y	0	39.2	y
188	2	0	0	0	2	0	0	2	y	y	0	55	y
189	10	3	3	0	6	1	7	0	y	y	0	40–53	y
190	1	1	1	0	1	0	1	0	y	y	0	26.7	y
191	11	1	7	0	4	0	0	4	2,680	1,520	0	46.2	y
192	776	8	547	0	229	0	0	229	y	y	0	17–21	y
193	1	0	0	0	1	0	0	1	x	x	0	35	y
194	16	0	y	y	8	0	7	1	3,100	x	0	42–45	y
195	5	0	0	0	5	0	4	1	x	x	0	38–50	y
196			Included with above									34.2–64	0.10
197	13	2	4	0	9	0	9	0	3,900	x	R	40	y
198	126	15	9	0	117	1	28	9	1,450	x	0	36–44	y
199		Included with above					78	3	950	x	0	36.8	y
200	1	0	y	y	y	y	y	y	y	y	0	55.7	y
201	4	1	1	0	3	0	3	0	y	y	0	35	y
202	51	0	7	0	42	2	39	5	574	550	0	36–43	y
203	5	0	y	y	y	y	y	y	550	y	0	46	y
204	13	10	0	0	12	1	13	0	y	y	0	35.6–57	y
205	806	11	646	0	160	0	7	153	y	y	0	16–31	y
206	20	3	5	0	15	0	14	1	y	y	0	37–52	y
207	91	2	0	0	91	0	68	23	2,085	2,019	0	19.5–25.5	y
208	317	8	277	0	40	0	5	35	50	y	0	21–47	y
209	5	5	2	0	3	0	0	y	y	y	0	y	y
210	10	2	0	0	0	0	10	y	1,300	y	0	y	y
211	1,385	1	1,240	0	145	0	4	141	x	x	0	25	y
212	5	0	y	y	y	y	y	y	2,000	y	0	69	y
213	5	1	4	0	1	0	1	0	x	y	0	32.5	y
214	1	0	0	0	1	0	1	0			0	32.5	y
215	1	1	0	0	0	1	1	0	y	y	0	y	3
216	1	0	0	0	1	0	1	0	y	y	0	34.5	y
217	71	0	20	0	51	0	36	15	1,570		0	28–35	y
218	6	3	3	0	2	1	y	y	900	y	0	27.8	y
219	3	2	2	0	1	0	y	y	x	y	0	52	y
220	2	0	y	0	y	y	y	y	0	y	0	30.6–52.3	y
221	373	5	20	0	353	0	320	33	2,430	y	0	25–43	y
222		6											
223	1	0	y	y	y	y	y	y	2,520	y	0	y	y
224	1	0	0	0	1	0	y	y	x	y	0	30.3	y
225	536	18	68	0	468	0	350	118	2,490	y	0	37–41	y
226	451	18	351	0	118	0	y	y	1,040	y	0	35.5	y

TABLE I.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
168	Frio	Olig	S	Por	7,830	9,275	10–15	D	Frio	11,327
169	Cockfield	Eoc	S	Por	3,860	3,900	19	Df	Wilcox	8,993
170	Cockfield	Eoc	S	32	3,616	3,926	15	Df	Mt. Salmen	7,569
171	Frio	Olig	S	33	4,596	4,790	10–25	A	Hockley	8,888
172	Mio, Frio, Vicksburg	Mio, Olig	S	Por	3,142	6,943	45*x*	Ds	Jackson	7,165
173	Heterostegina, Frio	Olig	S	Por	4,745	6,370	20	Af	Frio	7,242
174	Marginulina, Olig	Olig	S	Por	6,580	6,684	100	D	Vicksburg	8,061
175	Cockfield	Eoc	S	Por	3,036	4,277	*y*	NF	Cook Mt.	4,756
176	Marginulina	Olig	S	Por	6,240	6,250	10	DF	Frio	7,498
177	Pli, Mio	Pli, Mio	S	Por	3,150	5,930	22	Ds	Vicksburg	7,667
178	Frio, Olig	Olig	S	Por	5,920	5,942	40	Ds	Vicksburg	7,667
179	Mio	Mio	S	Por	4,628	4,635	7	Af	Miocene-Oligocene	6,652
180	Whittset, McElroy-Cockfield	Eoc	S	Por	3,149	4,124	18–35	Df	Wilcox	8,589
181				Included above						
182	Cockfield	Eoc	S	Por	3,888	3,944	15	Df	Yegua	4,253
183	Oakville, Catahoula, Frio	Mio, Olig	S	Por	3,687	6,770	30	Df	Vicksburg	9,225
184	Frio	Olig	S	30	4,900	6,600	30	Df	Vicksburg	9,225
185	Marginulina	Olig	S	34	3,545	5,900	10	D	Frio	7,300
186	Jackson, Yegua	Eoc	S	Por	1,275	?	6	Mf	*y*	3,000
187	Yegua	Eoc	S	Por	6,947	6,956	9	Af	Yegua	7,495
188	Cockfield	Eoc	S	Por	7,743		10	Df	Yegua	8,530
189	Frio	Olig	S	Por	8,538	8,554	18	*y*	Frio	10,010
190	Mio	Mio	S	Por	4,982	4,992	7	Ds	Miocene	6,721
191	Marginulina	Olig	S	30	6,480	6,500	3	T	Vicksburg	8,943
192	Cap rock, Mio, Olig	Cap rock. Mio, Olig	S	LS Por	500	3,320	17	Ds	Crockett	7,461
193	Frio, Vicksburg	Olig	S	Por	5,013	5,023	*x*	F	Yegua	6,702
194	Yegua	Eoc	S	Por	6,803	6,834	15	DF	Yegua	7,520
195	Cockfield	Eoc	S	Por	4,740	4,856	10	DF	*y*	*y*
196	Wilcox	Eoc	S	Por	4,740	7,820	10	DF	Wilcox	8,553
197	Frio	Olig	S	Por	*y*	*y*	*y*	*y*	Frio	9,637
198	Cockfield	Eoc	S	Por	5,150	5,200	10	AF		
199	Wilcox	Eoc	S	17.5	8,190	9,150	30	AF	Wilcox	11,734
200	Wilcox	Eoc	S	Por	8,215	8,277	*y*	*y*	Wilcox	8,590
201	Wilcox	Eoc	S	Por	8,133	8,144	7	*y*	Wilcox	10,836
202	Cockfield	Eoc	S	Por	6,845	6,965	20	DF	Cook Mt.	7,778
203	Yegua	Eoc	S	Por	4,199	4,404	10	DF	Yegua	4,580
204	Frio	Olig	S	Por	8,796	10,343	15	DF	Frio	10,419
205	Pli, Mio, Olig, Saline Bayou	Pli, Mio, Olig	S	Por	500	6,804	100	DS	Upper Saline Bayou	7,914
206	Frio	Eoc, Olig	S	Por	7,491	7,885	30	Ds	Frio	8,785
207	Mio, Frio	Mio, Olig	S	30	3,845	4,775	75	Ds	Cockfield	9,474
208	Mio, Olig, Yegua	Mio, Olig, Eoc	S	Por	700	4,996	100	Ds	Yegua	4,996
209	Cockfield	Eoc	S	Por	1,844	1,852	8	AF	Cockfield	2,448
210	Catahoula	Mio	S	Por	2,910	3,020	30	N?	Yegua	8,183
211	Cap rock, Mio, Pli, Frio	Cap rock, Pli, Mio-Olig	L S	Cav Por	800 2,920	1,200 5,900	*x* 69	Ds	Frio	7,382
212	Cockfield	Eoc	S	Por	5,835	5,824	5	D	Wilcox	11,794
213	Mio	Mio	S	Por	4,300	4,500	10	Ds	Mid. Oligocene	7,624
214	Frio	Olig	S	Por	7,604	7,618	14	?	Frio	9.335
215	Mio	Mio	S	Por	2,880	2,885	5	AF	Oligocene	6,406
216	Marginulina	Olig	S	Por	8,850	8,880	12*y*	DF	Frio	9,312
217	Heterostegina, Marginulina, Frio	Olig	S	25±	2,900	3,800	80	Ds	Saline Bayou	7,521
218	Catahoula, Frio	Mio, Olig	S	Por	2,525	3,600	*y*	Df	Cook Mt.	7,666
219	Frio	Olig	S	Por	5,686	5,770	10	Ds	Vicksburg	8,724
220	Wilcox	Eoc	S	14–43	7,855	7,922	18	?	Wilcox	8,518
221	Mio, Marginulina, Frio	Mio, Olig	S	25	3,050	5,409	80	D	Vicksburg	9,001
222	Vicksburg	Olig	S	25	7,700	7,800	100	D	Vicksburg	9,001
223	Frio	Olig	S	Por	5,875	5,890	10	*y*	Frio	7,010
224	Vicksburg	Olig	S	Por	5,274	5,282	*y*	?	Vicksburg	5,610
225	Cockfield, Yegua	Eoc	S	25*x*	2,045	5,682	10	DF	Wilcox	8,948
226	Frio	Olig	S	Por	5,176	5,948	100	ALF	Frio	8,174

were completed during the year as producers. The field appeared to be defined on the south. Several operators have holdings in the field and development is progressing in an orderly manner. This production is from the Yegua.

Coloma Creek Field, Calhoun County.—McSpadden Company's No. 1-A Elizabeth Clark was completed from a Miocene sand, through perforations at 5891 to 5892 ft., on Jan. 18, 1941, for 108 bbl. of 54° gravity distillate. The well was bottomed at 6240 ft. One dry hole was drilled in the area in 1941.

Fostoria Field, Montgomery County.—The discovery well of this field was the Atlantic Oil Producing Company's Foster Lumber Co. No. 1, which was completed through perforations at 5790 to 5794 ft. in the Cockfield sand, on Dec. 28, 1941, as a pumper making 39° gravity oil. The well previously had been drilled to a total depth of 11,794 ft., penetrating the Wilcox approximately 2700 ft. without securing production.

Fred Field, Tyler County.—Stanolind Oil and Gas Company's No. 1 J. F. Parker was completed on Nov. 2, 1941, for 218 bbl. of 39.5° gravity oil from perforations from 8180 to 8200 ft. in a Wilcox sand, after having been drilled to a total depth of 8500 ft. During 1941 no other wells were completed in this field.

Genevieve Field, Bee County.—The discovery well of this area was the J. R. Daugherty No. 1 R. T. Hicks, which was completed on March 5, 1941, from perforations from 4169 to 4178 ft. in the Pettus section (Cockfield), for 40 bbl. of 54° distillate. No other wells were drilled in this field during the year and no statement

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941
227	Tuleta, West, *Bee*	1932	160	0	1,913,215	42,320	*y*	*y*
228	Tulsita, *Bee*	1938	30	30	9,539	2,666	*y*	*y*
229	Turtle Bay, *Chambers*	1935	875	*y*	1,972,382	484,671	*y*	*y*
230	Vanderbilt, *Jackson*	1934			Included with West Ranch			
231	Victoria, *Victoria*	1939	200	*y*	214,299	110,849	*y*	*y*
232	Vienna, *Lavaca*	1941	40	*y*	*y*	*y*	*y*	*y*
233	Voss, *Bee*	1936	95	*y*	78,391	215	*y*	*y*
234	Webster (Friendswood), *Harris*	1937	4,000	*y*	8,995,708	2,964,708	*y*	*y*
235	Weser, *Goliad*	1936	140	*y*	21,004	19,254	*y*	*y*
236	West Beaumont, *Jefferson*	1936	650	*y*	3,929,674	815,674	*y*	*y*
237	West Columbia, *Brazoria*	1914	700	*y*	82,503,517	2,746,192	*y*	*y*
238	West Columbia (New), *Brazoria*	1936			Included with West Columbia			
239	West Ganado, *Jackson*	1940	*y*	*y*	79,698	76,060	*y*	*y*
240	West Garwood, *Colorado*	1941	160	*y*	*y*	*y*	*y*	*y*
241	West Orange, *Orange*	1937	250	0	2,424,605	708,985	*y*	*y*
242	West Ranch, *Jackson*	1938	4,860	0	6,026,836	3,650,836	*y*	*y*
243	West Silsbee, *Hardin*	1941	250	*y*	23,680	23,680	*y*	*y*
244	White Creek, *Live Oak*	1939	115	0	236,688	117,795	*y*	*y*
245	Willow Slough, *Chambers*	1937	850	*y*	448,751	81,506	*y*	*y*
246	Wilson Creek, *Matagorda*	1937	80	*y*	96,199	12,085	*y*	*y*
247	Withers, *Wharton*	1936	8,700	*y*	7,693,533	2,927,533	*y*	*y*
248	Withers (Five Corners) *Wharton*	1936			Included with Withers			
249	Woodsboro, *Refugio*	1941	*y*	*y*	33,119	33,119	*y*	*y*
250	Worth, *Bee*	1935	50	0	27,275	*x*	*y*	*y*

can be made as to the importance of this discovery.

Goodrich Field, Polk County.—Pan American No. 1-B, Texas Long Leaf Lumber Co., was completed in the Cockfield sand at 4000 to 4030 ft., for 112 bbl. of 34° gravity oil, on Nov. 20, 1941. The well had been drilled to a total depth of 9966 ft. in the Wilcox but failed to produce in this section.

Hall's Bayou Field, Brazoria County.—Strake Petroleum Company's No. 1 Lena P. Griffith was completed on June 1, 1941, from perforations of 10,175 to 10,180 ft. in the upper Frio sand. This well tested 550 bbl. of 47.5° gravity oil for several days but operations were unsatisfactory and the well was shut in. No further developments were conducted in this field during the year.

Lake Creek Field, Montgomery County.—Superior Oil Company's No. 1 A. P. McWhorter was completed in the Wilcox on Feb. 26, 1941, from perforations at 9212 to 9217 ft. for 130 bbl. of 61° gravity distillate, after having been drilled to a total depth of 9314 ft. During the year several wells completed in the Wilcox were drilled deeper into that horizon, one to a total depth of 13,300 ft. Numerous shows of gas and distillate were noted but no satisfactory tests were made at the greater depths. Existing information warrants consideration for this field as an important distillate discovery but developments are yet too meager to evaluate reserves.

Lake View Field, Wharton County.—W. R. Davis' No. 1 Hartman was completed as a gas well in a Miocene sand, through perforations at 3400 to 3411 ft., on May 29, 1941. The well was drilled into the Jackson at a total depth of 6752 ft.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	Completed to End of 1941	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F. Weighted Average	Sulphur, Per Cent
		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
227	75	0	*y*	*y*	*y*	*y*	*y*	*y*	792	*y*	0	44.5–50	*y*
228	3	0	*y*	*y*	*y*	*y*	*y*	*y*	1,450	*y*	0	45	*y*
229	39	2	2	0	37	0	33	4	2,958	2,861	0	32	*x*
230													
231	25	12	15	0	9	1	*y*	*y*	*y*		0	22.5	*y*
232	1	0	0	0	1	0	1	0	*y*	*y*	0	50	*y*
233	8	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	0	45	*y*
234	212	0	1	0	*y*	*y*	209	2	950	*y*	0	20–30	*y*
235	10	5	8	0	2	0	*y*	*y*	750	*y*	0	46.5	*y*
236	74	5	16	0	58	0	31	27	*y*	*y*	0	26–34	*y*
237	379	30	230	0	149	0	115	34	*y*	*y*	0	28	*y*
238									2,452	*y*	0	28	*y*
239	25	24	1	0	24	0	24	0	*y*	*y*	0	24.5	*y*
240	4	3	1	0	4	0	*y*	*y*	*y*	*y*	0	52.4	*y*
241	48	3	0	0	48	0	29	19	*y*	*y*	0	24.5	*y*
242	323	148	180	0	138	5	143	0	1,700	*y*	0	30.3	*y*
243	2	*y*	*y*	*y*	*y*	*y*	2	0	*y*	*y*	0	40.8	*y*
244	38	17	30	0	8	*y*	*y*	*y*	*x*	*y*	0	21	*y*
245	6	1	0	0	6	0	6	0	3,900	*y*	0	34–37	0.07
246	1	1	1	0	1	0	1	0	*y*	*y*	0	35–55	*y*
247	270	46	10	0	260	0	253	7	2,350	*y*	0	26.1	*y*
248									850	*y*	0	25.6	*y*
249	4	4	2	0	4	0	4	0	*y*	*y*	0	40–60	*y*
250	2	0	*y*	0	*y*	*y*	*y*	*y*	850	*y*	0	30.3	*y*

Present indications do not suggest a major discovery.

Lucky Field, Matagorda County.—Stanolind No. 1 Huebner was drilled to 10,500 ft., plugged back and perforated for completion at 8883 to 8886 ft. in a Frio sand, for 75 bbl. of 39° gravity oil, on March 21, 1941. Two dry holes were drilled in this area during the year and it is not considered a major discovery.

Magnolia Field, Montgomery County.—Glen H. McCarthy's No. 1 Sale was perforated in the Wilcox sand from 8448 to 8458 ft., on Oct. 10, 1941, with an initial production of 87 bbl. of 57.7° gravity distillate. No further development was completed during the year.

Maurbro Field (Laward), Jackson County. Humble Oil and Refining Company's No. 1-B Mauritz Brothers was completed in a Frio sand from 5220 to 5230 ft., on Feb. 11, 1941, for 526 bbl. of 24.4° gravity oil. This appears to be the outstanding discovery of the year. Twenty oil wells have been completed during this period.

Navidad Field, Jackson County.—W. S. Boyle and John Mayo No. 1 R. Terrell was completed as a Miocene gas well, on March 3, 1941, from a depth of 3788 to 3796 ft. No additional developments were carried on during 1941 in this area.

Needville Gas Field, Fort Bend County.—No. 1 Elizabeth M. Coyle, W. L. Goldston et al., was perforated in a Frio sand at 5176 to 5180 ft. and completed as a gas well, on Oct. 22, 1941. This area has long been considered as a likely prospect but it is doubtful that the Frio here will assume major importance, because this area is well defined by dry holes.

North Laward Field, Jackson County.—Moore and Ahern's No. 1 Burditt was

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
227	Cockfield, Jackson-Wilcox	Eoc	Sh	Por	3,065	7,535	11+	DF	Wilcox	7,921
228	Cockfield	Eoc	Sh	Por	3,504	3,590	26	DF	Cockfield	3,598
229	Marginulina, Frio	Olig	S	Por	6,550	8,497	8	[y]	Vicksburg	8,497
230										
231	Catahoula, Frio, Vicksburg	Mio, Olig	S	Por	2,551 3,035 4,776	2,635 3,094 4,781	10	NLF	Vicksburg	5,252
232	Wilcox	Eoc	S	Por	8,468	8,476	10	F?	Wilcox	8,524
233	Cockfield	Eoc	S	Por	3,985	4,017	5[y]	NF	Yegua	4,306
234	Frio	Olig	S	30	5,488	6,050	150	DF	Frio	8,452
235	Yegua, Cook Mt.	Eoc	Sh	Por	4,802	5,310	7	MCL	Cook Mt.	5,313
236	Mio, Olig	Mio, Olig	S	Por	4,560	6,756	10–20	DF	Vicksburg	8,501
237	Pli, Mio, Olig	Pli, Mio, Olig	S	Por	354	[y]	250±	Ds	Vicksburg	8,518
238	Frio, Oligocene	Olig	S	Por	5,200	5,784	100	Ds	Frio	6,930
239	Frio	Olig	S	Por	5,204	5,220	16	?	Vicksburg	6,604
240	Wilcox	Eoc	S	Por	9,423	9,438	12	?	Wilcox	10,012
241	Frio	Olig	S	Por	5,585	6,123	8	D	Frio	7,550
242	Frio	Olig	S	28.4	5,086	5,780	40	DS	Vicksburg	8,527
243	Cockfield	Eoc	S	Por	6,918	6,923	5	DF	Cook Mt.	7,778
244	Jackson	Eoc	S	Por	1,280 1,389	1,302 1,440	7	MLf	Jackson	1,785
245	Frio	Olig	S	25	8,400	8,860	10	D	Frio	9,044
246	Frio	Olig	S	Por	7,903	10,058	25	N	Frio	10,796
247	Marginulina, Frio	Olig	S	Por	5,470	5,560	50	DF	Vicksburg	9,200
248	Frio	Olig	S	Por	5,540	5,550	8	DF	Vicksburg	9,200
249	Frio	Olig	S	Por	5,833	6,500	5	AF	Frio	6,710
250	Cockfield	Eoc	Sh	Por	3,407	?	5	D	Cockfield	3,708

perforated in the Frio sand at 5207 to 5226 ft., on Sept. 29, 1941, for 122 bbl. of 25.8° gravity oil. Developments have progressed rapidly throughout the year; 11 additional oil wells have been completed. It is considered that the North Laward field ranks second to the Maurbro field in 1941 discoveries.

Oyster Bayou Field, Chambers County.—The Sun Oil Company's No. 3 Felix Jackson was completed in the Frio sand from 8250 to 8280 ft., for 666 bbl. of 35.9° gravity oil, on Apr. 26, 1941. Developments during the year were meager, but it is understood that operators regard this field as a possible major oil field.

TABLE 2.—*Summary of Drilling Operations in Coastal Texas*

Important Wildcats Drilled in 1941

	County	Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Aransas	Blassman	11,472	Alluvium	Frio
2	Bee	Tool	5,309	Lizzie-Goliad	Vicksburg
3	Bee	M. Urangg	4,187	Lizzie-Goliad	Pettus (Cockfield)
4	Brazoria	Sec 7	10,060	Alluvium	Frio
5	Brazoria	Harry Dustin	5,622	Alluvium	Mio
6	Brazoria	George Tennille	8,518	Alluvium	Frio
7	Brazoria	Wm. Parker	9,564	Alluvium	Frio
8	Brazoria	H. P. Coyce	10,412	Alluvium	Frio
9	Calhoun	T. Hannesse	6,240	Beaumont	Mio
10	Calhoun	Tract 177—San Antonia Bay	6,406	Beaumont	Mio
11	Chambers	D. L. Broussard	9,785	Beaumont	Frio
12	Chambers	Sec. 46	8,964	Beaumont	Frio
13	Chambers	Sec. 126	8,294	Beaumont	Frio
14	Chambers	Sec. 223	10,924	Beaumont	Frio
15	Colorado	Winn	10,251	Lagarto	Wilcox
16	Colorado	Wooley	10,012	Beaumont	Wilcox
17	Fort Bend	H. D. Brown	8,090	Beaumont	Yegua
18	Fort Bend	H. & T. C. Sec. 29	6,463	Beaumont	Frio
19	Galveston	S. F. Austin ABT. 3	11,402	Beaumont	Frio
20	Hardin	F. P. Elliott	7,049	Lizzie	Cockfield
21	Harris	Whitney Britton	4,153	Lizzie	Mio
22	Jackson	Morris & Cummings No. 3	7,632	Lizzie	Frio
23	Jackson	Austin 2 Leagues	6,460	Lizzie	Frio
24	Jackson	Keller League	5,010	Lizzie	Frio
25	Jackson	Wells League	5,780	Lizzie	Frio
26	Jackson	Menefee	6,285	Lizzie	Marguinulina
27	Jackson	Menefee	5,480	Lizzie	Frio
28	Jackson	Rogers	6,621	Beaumont	Frio
29	Jackson	Menefee	6,815	Beaumont	Frio
30	Jackson	Murphy	6,025	Beaumont	Mio
31	Jackson	B. J. White League	5,940	Beaumont	Marginulina
32	Jackson	Young Sur. No. 3	6,513	Beaumont	Marginulina
33	Jefferson	State Gulf 1-71	7,071	Beaumont	Mio
34	Jefferson	T. & N. O. 158	9,313	Beaumont	Frio
35	Jefferson	T. & N. O. 173	9,500	Beaumont	Frio
36	Lavaca	C. P. Delmes ½ League	10,998	Goliad	Wilcox
37	Lavaca	M. Muldoon	8,524	Lagarto	Wilcox
38	Liberty	Jesse Devore	6,147	Beaumont	Yegua
39	Live Oak	Lot 3408 Block 72	1,856	Catahoula	Jackson
40	Matagorda	Elisha Hall	9,700	Beaumont	Frio
41	Matagorda	Thomas Cayce	8,107	Beaumont	Frio
42	Matagorda	Elisha Hall	10,500	Beaumont	Frio
43	Montgomery	P. Gill	11,794	Willis	Cockfield
44	Montgomery	T. J. Nichols	9,314	Willis	Wilcox
45	Montgomery	John Scott	10,008	Willis	Wilcox
46	Polk	A. Viesca 7 League	9,966	Lagarto	Cockfield
47	Refugio	A—Reojas	5,908	Beaumont	Frio
48	Tyler	G. T. W. Collins	8,500	Lizzie	Wilcox
49	Victoria	Manchola Z Leagues	4,732	Goliad	Frio
50	Victoria	Manchola Z Leagues	7,860	Goliad	Frio
51	Victoria	Gallardo	4,890	Goliad	Frio
52	Victoria	Creanor	5,960	Goliad	Frio
53	Wharton	I. & G. N. Sec. 10	6,752	Beaumont	Mio

N. H. = new horizon.
D = discovery well.

Sabine Pass Field, Jefferson County.—The British American Producing Company's No. 1-B State was completed at 4982 to 4992 ft., in a Miocene sand, for 290 bbl. of 26.7° gravity oil, on March 31, 1941. Developments have been slow because the field lies a short distance off shore in the Gulf of Mexico and the dome, in which salt has been encountered, has not been outlined.

South White Creek Field, Live Oak County.—Stelzig and Clark's No. 1 J. A. Everett was completed in a Jackson sand for 550 bbl. of 20° gravity oil from 1846 to 1856 ft., on Oct. 6, 1941. Two additional oil wells and two dry holes had been

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1941

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Continental Oil Co.	90	2.5	12/64	4,600	4,200	N. H. St. Charles field
2	Heyser-Heard et al.	35	y	8/64	1,825	1,975	N. H. Heard field
3	Daugherty	40	y	16/64	1,150	570	D. Genevieve
4	Phillips Petr. Co.	283	y	16/64-6/64	3,250	3,200	N. E. Chocolate Bayou
5	Rowan Drill. Co.	404	y	12/64	1,050	350	N. H. Danbury field
6	S. W. Richardson	167	y	12/64	2,300	2,150	N. H. West Columbia
7	J. Newton Rayzor	453	y	16/64	1,225	860	D. Chanango
8	Strake Petr. Co.	550	y	12/64	Sealed	450	D. Halls Bayou
9	McSpadden	108	y	16/64	2,050	1,700	D. Coloma Creek
10	Gulfboard	0	32	16/64	Sealed	1,000	D. Steamboat Pass
11	Sun Oil Co.	3	5.595	18/64	Sealed	3,000	N. H. Fig Ridge
12	Humble O. & R. Co.	173	y	8/64	Sealed	1,450	N. H. Fishers Reef
13	Sun Oil Co.	666	y	16/64	Sealed	1,160	D. Oyster Bayou
14	Humble O. & R. Co.	60	y	8/64	Sealed	2,975	N. H. Red Fish Reef
15	Shell Oil Co.	144	y	16/64	1,850	1,675	N. H. Sheridan
16	Davis & Co.	83	y	16/64	1,650	1,375	D. West Garwood
17	Providence Oil Co.	107	y	9/64	2,750	2,600	D. Clodine
18	Goldson et al.	0	1.5	12/64	2,150	1,950	D. Needville
19	Phillip's Petr. Co.	338	y	16/64		3,425	N. H. League City
20	Republic Prod. Co.	206	y	8/64	2,100	1,675	D. West Silsbee
21	J. W. Frazier	273	y	16/64	275	150	N. H. Dyersdale
22	The Texas Co.	355	y	12/64	Sealed	1,620	N. H. Ganado
23	Magnolia Petr. Co.	0	2.2	24/64	2,150	1,850	N. H. Lolita
24	Boyles et al.	0	1	12/64	1,683	1,577	N. H. Navidad
25	Sinclair Prairie	177	y	9/64	150	560	N. H. Texana
26	Pure Oil Co.	102	y	8/64	210	525	N. H. West Ganado
27	Pure Oil Co.	111	y	8/64	340	630	N. H. West Ganado
28	Pure Oil Co.	0	1.5	10/64	0	2,250	N. H. West Ganado
29	Pure Oil Co.	168	y	10/64	920	920	N. H. West Ganado
30	Boyles et al.	0	5.19	8/64	1,700	1,300	D. Navidad
31	Humble O. & R. Co.	526	y	16/64	625	650	D. Maurbro
32	Moore & Ahem	122	y	8/64	660	600	D. N. Laward
33	Hall Jordon et al.	291	y	8/64		300	D. Sabina Pass
34	G. H. McCarty	483	y	8/64	1,925	950	D. Stowell
35	Stanolind O. & G. Co.	0	4.795	8/64	950	3,530	D. Big Hill
36	Shell Oil Corp.	180	y	16/64	Sealed	2,500	D. Brushy Creek
37	McMurrey et al.	150	y	8/64-16/64	2,900	1,250	D. Vienna
38	South Oil Co.	518	y	10/64	Sealed	2,350	N. H. Hull
39	Stelzig et al.	552	y	32/64	425	200	D. South White Creek
40	Stanolind O. & G. Co.	181	y	8/64	975	850	N. H. Lucky
41	Sun Oil Co.	158	y	8/64	400	1,050	N. H. North Markham
42	Stanolind O. & G. Co.	75	y	8/64	Sealed	950	D. Lucky
43	Atlantic O. & P. Co.	Pumper	y				D. Fostoria
44	Superior O. & G. Co.	130	y	12/64	0	1,795	D. Lake Creek
45	McCarthy	87	y	16/64	Sealed	1,510	D. Magnolia
46	Pan American P. Co.	112	y	16/64	Sealed	150	D. Goodrich
47	Southern Minerals	55	y	28/64	1,930	575	D. Woodsboro
48	Stanolind O. & G. Co.	218	y	12/64	1,200	350	D. Fred
49	American Liberty	0	2	7/64	1,435	1,425	N. H. Coletto Creek
50	Plummer	0	25	44/64	1,850	1,800	N. H. Coletto Creek
51	Cox & Hamon	77	y	7/64	1,740	1,750	N. H. Cologne
52	Barnsdall O. & R. Co.	85	y	6/64	1,300	860	N. H. North McFaddin
53	W. R. Davis & Co.	0	1.7	10/64	580	360	D. Lakeview

completed in the area during the year. This field has not developed sufficiently to determine the importance of this discovery.

Steamboat Pass Gas Field, Calhoun County.—Gulfboard No. 1 State (Tract 177), in San Antonio Bay, was completed as a Miocene gas well on May 14, 1941, through perforations at 2880 to 2885 ft. No other development was undertaken during the year. This is not considered to be a major discovery.

Stowell Field, Jefferson County.—No. 1 Smith and Crawford, Glen H. McCarthy et al., was completed on Dec. 10, 1941, from a Frio sand, through perforations at 8550 to 8580 ft. for 483 bbl. of 34.5° gravity oil. Considerable interest has been evidenced in this discovery but developments have not been sufficient to indicate its importance.

Vienna Field, Lavaca County.—No. 1 Allen, McMurrey et al., was completed as a Wilcox producer of 50° gravity distillate, through perforations at 8468 to 8476 ft., on Feb. 16, 1941, after having been drilled to a total depth of 8524 ft. in the Wilcox. No further development was undertaken during the year.

West Garwood Field, Colorado County.—No. 1-A Brouson, W. R. Davis and Company, Inc., was completed in a Wilcox sand at 9423 to 9438 ft. on Jan. 30, 1941, for 83 bbl. of 52.4° gravity distillate. Four additional oil wells were completed in 1941 in this area but developments have not been sufficient to warrant consideration of this field as a major development.

West Silsbee Field, Hardin County.—Republic Production Company and Houston Oil Company's No. 1 Elliott Fee was completed on Apr. 14, 1941, at a depth of 6923 ft., for 206 bbl. of 40.8° gravity oil, from the Cockfield sand. This is not considered to be a field of major importance at this time.

Woodsboro Field, Refugio County.—Southern Minerals Corporation's No. 1 R. H. Wood was completed through perforations at 5900 to 5903 ft., from a Frio sand, for 55 bbl. of 40° gravity oil, on March 30, 1941. Two additional oil wells and two dry holes were drilled during the year, and it is not considered to be a major discovery.

New Horizons

Development during the year resulted in the discovery of new producing horizons in the West Ganado, Texana, Lolita and Ganado fields in Jackson County; the Sheridan and Garwood fields in Colorado County; the Coletto Creek, Cologne and North McFadden fields in Victoria County; the St. Charles field in Aransas County; the Hurd field in Bee County; the Chocolate Bayou, Danbury and West Columbia fields in Brazoria County; the Dyersdale field in Harris County; the Fig Ridge, Fisher's Reef and Red Fish Reef fields in Chambers County; Hull field in Liberty County; League City field in Galveston County; and the Lucky and North Markham fields in Matagorda County.

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Oil and Gas Development and Production in North Texas for the Year 1941

By Lewis W. MacNaughton,* Member A.I.M.E., and F. L. Burchard†

The North Texas district, as herein defined, includes the counties of Archer, Baylor, Clay, Cooke, Foard, Hardeman, Knox, Montague, Wichita, and Wilbarger. This area covers generally the crest and south flank of a system of buried mountains known as the Red River uplift. The oil and gas accumulations along this feature are in traps, which, although localized by structures incident to the regional uplift, are usually modified by stratigraphic changes in the sediments. Excepting the fields in southeastern Baylor, southern Archer, and southwestern Clay Counties, all the fields within the district are on this Red River uplift. These exceptions, which have the same type of oil and gas accumulation as the other fields, are on the extreme north end of the Bend arch, which is a broad anticline plunging northward from the Llano uplift in central Texas to Archer County. The larger part of past oil and gas production has come from Pennsylvanian strata, with less important amounts from the Permian, and minor but increasingly important quantities from the Ordovician.

DEVELOPMENTS DURING 1941

Nearly 1600 wells were drilled in the district during 1941 as compared with more than 1700 in 1940. However, the ratio of successful drilling operations was higher and some 1200 oil wells were completed.

Production held about even with the previous year, as did the number of producing oil wells. Known oil reserves increased slightly throughout exploration, which generally was carried on at greater depths than in former years. The average depth of discovery wells was 300 ft. deeper than in 1940. Although discoveries were evenly divided numerically between horizons above the base of the Strawn series and those below the Strawn, the deeper horizons, including the Bend series of the Pennsylvanian, the Mississippian limestone, and the Simpson and Ellenburger of the Ordovician, furnished most of the increase in oil reserves.

The largest single addition to the reserves was in the Ellenburger formation in the K.M.A. field. During the year 112 wells were completed in this horizon, bringing the total developed acreage to some 4600 acres. The Strawn series in K.M.A. also received considerable development in 1941, with 114 completions.

K.M.A. PRESSURE MAINTENANCE

Satisfactory progress was made by the K.M.A. Pressure Maintenance Association in 1941. At the end of the year, 99 wells were being used for input and total monthly volume of gas returned to the reservoir reached a high of 340,548 M cu. ft. in December from a low of 208,853 M cu. ft. in February. Total volume of gas returned during 1941 was 3,306,052 M cu. ft. To the end of the year, 150 cu. ft. of gas had been returned for every barrel of oil produced from the reservoir while the input ratio for December was 397 cu. ft. per

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TABLE 1.—*Oil and Gas Production in North Texas District*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil Wells				
			Oil	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941	
							Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]
	Archer County:									
1	Blewett	1940	100	42,455	30,636	11	1	0	0	11
2	Chalk Hill deep	1931	600	3,031,807	87,827	*y*	0	*y*	*y*	36
3	Colgan	1939	100	52,256	32,063	9	0	0	0	9
4	Hull-Silk	1938	7,000	7,120,904	3,959,472	441	54	*y*	0	441
5	Kadane-deep (Griffin)	1939	500	147,727	94,924	17	14	0	0	17
6	Kadane-shallow (Griffin)	1939	80	16,389	7,105	6	2	0	0	6
7	Mankins	1939	500	395,318	262,197	14	1	0	0	14
8	McCrory	1938	20	33,082	7,071	1	0	0	0	1
9	Meade	1940	50	13,444	12,761	7	4	0	0	7
10	Moer (Scotland)	1938	20	17,709	4,252	1	0	0	0	1
11	Pan-Taylor	1941	40	1,931	1,931	1	1	0	0	1
12	Scotland (Coleman)	1940	480	81,633	79,760	17	16	0	0	17
13	Vogtsberger	1940	120	42,679	30,288	3	1	0	0	3
14	All other fields		*y*	119,388,778	2,978,286	*y*	170	*y*	*y*	3,415
	Total Archer County			130,386,112	7,588,573	*y*	264	*y*	*y*	3,979
	Baylor County:									
15	Portwood	1924	600	4,814,249	200,286	188	0	3	0	144
16	Rendham	1940	480	65,495	51,608	12	8	0	0	12
17	Seymour	1939	1,480	544,110	327,337	33	13	0	0	33
	Clay County:									
18	Antelope (Henderson)	1939	820	279,839	234,602	50	35	0	0	49
19	Antelope-Mississippi	1941	40	13,154	13,154	1	1	0	0	1
20	Apache	1940	40	3,368	1,198	2	1	0	0	2
21	Boddy	1938	300	42,498	37,276	33	31	0	0	33
22	Burns-Browning (Burns)	1939	320	141,122	39,994	5	2	0	0	5
23	Costley	1939	40	48,231	12,057	10	0	0	0	10
24	Edrington	1932	500	[1]	253,545	116	5	2	0	114
25	Halsell	1939	1,000	204,888	131,694	9	0	0	0	9
26	Hapgood	1940	120	73,230	54,717	3	0	0	0	3
27	Howard	1940	40	9,061	5,275	1	0	0	0	1
28	Joy	1940	40	3,060	3,060	1	0	0	0	1
29	Kinder	1939	40	8,226	4,005	1	0	0	0	1
30	Knox-Finley	1923	700	[1]	129,579	106	51	6	0	95
31	McInniss (Glasgow)	1940	350	209,808	147,461	67	30	1	0	59
32	Nebraska	1922	100	[1]	9,658	3	2	0	0	2
33	New York City	1941	320	33,421	33,421	5	5	0	0	5
34	Petrolia	1902	3,000	[1]	96,189	*y*	1	*y*	*y*	407
35	Ross (Jolly)	1939	480	94,274	71,629	11	8	0	0	11
36	Shumake	1937	520	527,312	132,604	78	19	0	0	78
37	Spring	1941	40	809	809	1	1	0	0	1
38	Taylor (Costley So.)	1940	200	106,149	94,515	51	38	0	0	51
39	Worsham	1923	200	[1]	31,361	13	1	0	0	7
40	Wright-Barry	1926	60	[1]	2,493	11	0	0	0	5
	Total Clay County		9,270	10,834,099	1,540,296	*y*	231	*y*	*y*	950

[c] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Included in county total.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift						Top Prod. Zone	Bottoms Prod. Wells				
1	0	11	38	Cisco	Pen	S	Por	1,425	1,450	y	ML	Cisco	1,557
2	0	36	42	Canyon Strawn	Pen Pen	S	Por Por	2,200 3,600	2,225 3,640	20	A	Bend	5,748
3	0	9	40	Cisco	Pen	S	Por	1,453	1,461	8	MC	Cisco	1,500
4	256	185	42–44	U. Strawn M. Strawn L. Strawn Bend	Pen Pen Pen Pen	S L S L	Por Por Por Por	3,800 3,980 4,280 4,620	3,860 4,050 4,380 4,630	15 12 30 10	A	Ellenburger	5,272
5	14	3	42	Strawn	Pen	S	Por	4,337	4,351	10	A	y	4,901
6	0	6	42	Cisco	Pen	S	Por	1,630	1,640	8	AM	Strawn	4,410
7	9	5	43	Bend	Pen	L	Por	4,660	4,690	30	A	y	4,918
8	1	0	41	Bend	Pen	L	Por	4,735	4,760	20	N	Bend	4,696
9	0	7	38	Cisco	Pen	S	Por	954	960	5	y	Cisco	1,407
10	0	1	40	Strawn	Pen	S	Por	4,135	4,138	3	y	Strawn	4,138
11	0	1	y	Miss. Lime	Mis	L	Por	4,927	4,949	y	y	Mississippi	5,051
12	15	2	42	Strawn Bend Miss. Lime	Pen Pen Mis	S S L	Por Por Por	4,016 5,042 5,550	4,032 5,058 5,560	10	A	Ellenburger	5,850
13	3	0	41	Strawn	Pen	S	Por	4,656	4,671	15	y	Ellenburger	5,335
14	3	3,412											
	301	3,678										Ellenburger	5,850
15	0	144	36	Gunsight	Pen	S	Por	1,340 1,390	1,370 1,400	y	ML	Strawn	4,265
16	0	12	31	Canyon	Pen	L	Por	3,025	3,060	y	M	Strawn	4,326
17	16	17	y	U. Canyon	Pen	L	Por	2,525	2,605	20	N	y	5,598
18	47	2	40	Strawn Bend	Pen Pen	S L	Por Por	3,190 5,451	3,250 5,480	25 y	AM	Ellenburger	6,100
19	1	0	40	Chappel	Mis	L	Por	5,670	5,760	y	AM	Ellenburger	6,100
20	0	2	y	Cisco	Pen	S	Por	1,125	1,140	y	y	Cisco	1,366
21	0	33	y	Cisco	Pen	S	Por	1,050 1,110	1,060 1,120	10	y	Cisco	1,330
22	1	4	44	Strawn	Pen	S	Por	4,430	4,460	20	A	Ellenburger	6,014
23	0	10	40	Cisco	Pen	S	Por	1,035 1,150	1,050 1,160	18	y	Cisco	1,406
24	0	114	38	y Cisco	Per Pen	S S	Por Por	325 1,090	350 1,120	15	N	y	2,064
25	9	0	39	Strawn	Pen	S	Por	4,720	4,800	y	A	Ellenburger	6,048
26	1	2	45	Bend	Pen	Cgl	Por	5,972 6,023	5,994 6,033	20	A	Ellenburger	6,538
27	0	1	44	Bend	Pen	L	Por	5,460	5,488	15	y	Bend	5,606
28	1	0	y	Chappel	Mis	L	Por	5,905	5,967	y	y	Mississipp	6,088
29	0	1	37	Strawn	Pen	S	Por	4,130	4,150	15	AM	Bend	5,527
30	0	95	y	y Cisco	Per Pen	S S	Por Por	280 1,110	300 1,145	10	A	Cisco	1,716
31	0	59	y	y Cisco	Per Pen	S S	Por Por	250 1,070	260 1,120	10	y	Cisco	1,404
32	2	0	y	Strawn Bend	Pen Pen	S L	Por Por	3,337 5,777	3,405 5,790	10 10	N	Ellenburger	6,098
33	5	0	45	Chappel	Mis	L	Por	6,180	6,280	y	y	Ellenburger	6,837
34	0	407	30	y Cisco	Per Pen	S S	Por Por	230 760 1,000 1,720	300 780 1,020 1,780	12 10 10 15	A	Pre-Cambrian	4,289
35	11	0	41	Bend	Pen	L	Por	5,350	5,400	40	AM	Ellenburger	5,846
36	0	78	y	Cisco	Pen	S	Por	1,130	1,200	15	ML	Cisco	1,945
37	1	0	48	Bend	Pen	L	Por	5,588	5,630	y	y	Bend	5,630
38	0	51	y	Cisco	Pen	S	Por	1,120	1,150	15	y	Cisco	1,852
39	0	7	38	Strawn Bend Ellenburger	Pen Pen Ord	S L D	Por Por Por	3,400 3,925 5,588 5,780	3,440 3,980 5,669 5,792	10 20 y y	A	Ellenburger	6,163
40	0	5	40	Cisco	Pen	S	Por	840	860	y	ML	Strawn	4,112
	79	871											

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil Wells				
							During 1941		End of 1941	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]
	Cooke County:									
41	Anderson (Gainesville)	1935	880	3,484,609	350,633	127	4	4	0	123
42	Big Indian (Callisburg)	1925	20	[1]	2,555	1	0	0	0	1
43	Bindel	1941	60	18,521	18,521	6	6	0	0	6
44	Bulcher	1926	580	[1]	209,248	*y*	0	*y*	*y*	139
45	Huggins	1929	160	[1]	14,102	*y*	0	*y*	*y*	29
46	Osburn	1941	10	579	579	1	1	0	0	1
47	Talbott	1936	40	27,872	3,730	6	0	0	0	3
48	T.C.U.	1939	300	89,123	63,044	46	30	0	0	46
49	Trew	1936	260	794,446	65,898	44	0	0	0	44
50	Voth	1938	650	428,326	174,632	62	24	0	0	62
51	Walnut Bend	1938	1,450	2,634,468	1,090,232	124	35	0	0	124
52	Wilson	1941	120	10,416	10,416	6	6	0	0	6
53	All other fields		*y*	15,485,124	878,176	*y*	79	*y*	*y*	605
	Total Cooke County		*y*	22,973,484	2,881,766	*y*	185	*y*	*y*	1,189
	Foard County:									
54	Allee	1940	120	17,334	8,513	5	0	2	1	2
55	Johnson	1933	380	1,622,751	114,426	16	0	0	0	11
56	Thalia	1927	180	327,484	11,278	13	0	0	0	5
	Montague County:									
57	Beck	1933	260	[1]	92,940	*y*	3	0	0	54
58	Benson	1941	60	15,755	15,755	2	2	0	0	2
59	Bonita	1940	380	381,222	228,401	20	3	0	0	20
60	Bowers (Benton and Holmes)	1939	760	382,830	244,249	32	16	0	0	28
61	Chapman and McFarlin	1941	20	4,275	4,275	1	1	0	0	1
62	Clingingsmith	1941	160	23,554	23,554	4	4	0	0	4
63	Holt	1936	240	725,499	92,020	37	0	0	0	37
64	Hults and Owens	1940	80	37,625	27,487	4	3	2	0	2
65	Nocona	1918	3,200	[1]	1,192,841	*y*	*y*	*y*	*y*	824
66	Ringgold	1940	360	198,874	134,853	9	1	0	0	9
67	Rogers and Rogers (Nocona Townsite)	1939	860	1,170,245	462,558	45	10	0	0	45
68	Seitz	1933	300	[1]	175,763	*y*	0	1	*y*	44
69	Stoneburg	1941	40	666	666	1	1	0	0	1
70	Thomas	1941	20	1,166	1,166	1	1	0	0	1
71	Turner	1941	40	4,893	4,893	1	1	0	0	1
	Total Montague County		6,780	35,541,603	2,701,421	*y*	5*y*	*y*	*y*	1,073

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift						Top Prod. Zone	Bottoms Prod. Wells				
41	0	123	41	U. Strawn	Pen	S	Por	1,605	1,615	10	AM	y	2,710
				L. Strawn	Pen	S	Por	1,950	1,970				
42	0	1	47	Strawn	Pen	S	Por	3,518	3,529	11	y	Strawn	3,529
43	1	5	38	Strawn	Pen	S	Por	1,885	1,896	10	A	Ellenburger	3,247
				Ellenburger	Ord	L	Por	3,242	3,247	5			
44	0	139	y	U. Strawn	Pen	S	Por	1,125	1,130	y	MC	y	2,042
				L. Strawn	Pen	S	Por	1,310	1,318				
				U. Ellenburger	Ord	L	Por	1,403	1,408				
				M. Ellenburger	Ord	L	Por	1,540	1,550				
				L. Ellenburger	Ord	L	Por	1,751	1,753				
45	0	29	y	Strawn	Pen	S	Por	1,150	1,190	10	N	y	y
46	0	1	y	Strawn	Pen	S	Por	2,309	2,320	10	y	Strawn	2,320
47	0	3	40.5	Strawn	Pen	S	Por	1,650	1,700	5	N	y	3,100
48	0	46	30	Strawn	Pen	S	Por	1,125	1,143	8	A	y	2,163
49	0	44	37	Strawn	Pen	S	Por	1,475	1,485	8	AM	Pennsylvanian	2,095
50	0	62	39	Ellenburger	Ord	L	Por	1,725	1,735	10	y	Ellenburger	1,793
51	4	120	34	U. Strawn	Pen	S	Por	4,108	4,125	7	N	y	6,110
				M. Strawn	Pen	S	Por	4,887	4,895	7			
				L. Strawn	Pen	S	Por	5,141	5,173	20			
				Simpson	Ord	L	Por	5,206	5,242	30			
				Ellenburger	Ord	L	Por	5,413	5,565	30			
52	0	6	41.7	U. Strawn	Pen	S	Por	2,221	2,227	10	AM	L. Strawn	2,380
				L. Strawn	Pen	S	Por	2,360	2,380				
53	1	604											
	6	1,183											
54	0	2	33	Canyon	Pen	L	Por	2,360	2,370	10	A	Canyon	2,370
55	1	10	50	Canyon	Pen	L	Por	3,600	3,625	y	A	Pre-Cambrian	5,003
56	0	5	39	Thalia	Pen	S	Por	y	y	y	A	Pre-Cambrian	2,550
				Cisco	Pen	L	Por	2,500	2,550	22			
57	0	54	39	Canyon	Pen	y	Por	1,400	2,330	y	AL	y	2,484
				Strawn	Pen	S	Por	2,471	2,484	y			
58	2	0	y	Bend	Pen	L	Por	5,840	5,850	10	y	Bend	5,789
59	15	5	40	Strawn	Pen	S	Por	5.240	5,249	9	A	Ellenburger	6,975
				Bend	Pen	S	Por	5,443	5,458	15			
60	15	13	39	Canyon	Pen	L	Por	2,020	2,030	10	A	Pre-Cambrian	4,300
						L	Por	2,280	2,320	12			
				Strawn	Pen	S	Por	2,880	2,920	10			
						S	Por	3,450	3,490	20			
						S	Por	3,850	3,870	15			
61	1	0	y	Strawn	Pen	S	Por	4,840	4,857	y	y	Ellenburger	6,008
62	3	1	y	Bend	Pen	Cgl	Por	6,120	6,130	10	N	Bend	6,131
63	0	37	32	Canyon	Pen	LS	Por	1,700	1,765	5	AM	Pre-Cambrian	3,648
64	2	0	y	Caddo	Pen	L	Por	6,016	6,050	y	y	Bend	6,070
65	0	824	22–42	Cisco	Pen	S	Por	575	1,700	y	A	y	y
				Canyon	Pen	LS	Por	1,790	2,080	y			
				Strawn	Pen	S	Por	4,315	4,345	y			
				Bend	Pen	L	Por	5,228	5,250	y			
66	9	0	47	U. Bend	Pen	Cgl	Por	5,690	5,705	15	N	Ordovician	6,092
				L. Bend	Pen	Cgl	Por	5,790	5,795	5			
				Ellenburger	Ord	L	Por	5,800	5,875	20			
67	34	11	42	U. Strawn	Pen	S	Por	4,280	4,300	y	A	Ellenburger	6,988
				L. Strawn	Pen	S	Por	4,650	4,680	y			
				Bend	Pen	Cgl	Por	5,125	5,135	y			
				Caddo	Pen	L	Por	5,230	5,250	y			
68	0	44	37	Canyon	Pen	S	Por	1,610	1,615	y	AL	y	2,741
				U. Strawn	Pen	S	Por	1,755	1,770	y			
				L. Strawn	Pen	S	Por	2,015	2,020	y			
69	1	0	y	Nocona	Pen	L	Por	6,233	6,241	8	y	Viola	6,610
70	0	1	y	Strawn	Pen	S	Por	3,023	3,045	y	y	Ellenburger	4,646
71	1	0	y	Bend	Pen	Cgl	Por	6,222	6,234	12	y	Ellenburger	7,326
	83	990											

barrel. This represents a utilization of 29 per cent of the gas available for return during that month.

The Association continually strives toward minimum producing gas-oil ratios. These ratios can be controlled by adjustment of input volume and pressure by the Association and rate of production by the lease operators.

Results of the repressuring program are becoming increasingly favorable as the Association's plans are developed.

OUTLOOK FOR 1942

The tendency toward deeper exploration in the district noted during the past two years should continue and further develop-

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Number of Oil Wells				
							During 1941		End of 1941	
			Oil	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]
	Wichita County:									
72	Asylum (State Hospital)	1938	80	67,206	22,411	3	0	0	0	3
73	Jackson	1938	300	175,563	45,267	22	0	0	0	20
74	K.M.A.-Ellenburger	1940	4,600	624,760	616,352	115	112	0	0	115
75	K.M.A.-Strawn	1931	29,500	35,011,871	9,612,690	16*yy*	114	*y*	*y*	1,595[2]
76	Oates	1940	140	96,625	94,241	36	30	0	0	36
77	Underwood	1939	60	50,547	22,859	10	0	1	0	9
78	All other fields		*y*	320,316,550	4,602,710	*y*	*y*	*y*	*y*	5,761
	Total Wichita County			356,343,122	15,016,530	*y*	*y*	*y*	*y*	7,539
	Wilbarger County:									
79	Castleberry	1937	200	400,351	115,335	23	0	0	0	23
80	Consolidated	1939	600	776,098	320,724	43	12	0	0	43
81	Consolidated-Ellenburger	1941	120	6,952	6,952	1	1	0	0	1
82	Electra-Ellenberger	1941	80	7,461	7,461	2	2	0	0	2
83	Fargo	1940	1,800	359,147	350,335	44	38	0	0	44
84	Fluhman	1926	200	[1]	14,564	22	0	0	0	13
85	Harrold	1940	160	32,971	32,971	6	6	0	0	6
86	King (Pois-Schultz)	1939	80	63,027	20,896	10	1	0	0	10
87	King-Lawson	1936	20	20,664	2,816	2	0	0	0	2
88	King-Waggoner	1936	120	116,826	18,938	10	0	0	0	10
89	Lawson	1935	80	248,124	28,184	15	0	0	0	15
90	Millham	1925	100	[1]	7,903	14	0	0	0	9
91	Phillips-King	1938	120	94,872	30,019	6	0	0	0	6
92	Rock Crossing-Canyon	1937	300	[1]	108,516	28	10	0	0	28
93	Rock Crossing-Ellenburger	1941	120	8,310	8,310	3	3	0	0	3
94	Zenith	1930	80	[1]	6,699	12	0	0	0	8
95	All other fields		*y*	73,598,687	2,177,659	*y*	*y*	*y*	*y*	1,489
	Total Wilbarger County		*y*	75,773,490	3,258,282	*y*	*y*	*y*	*y*	1,712
	TOTAL NORTH TEXAS DISTRICT			639,243,333	33,700,316		1,213			16,649

[2] Includes 99 wells used for gas input; allowable for these wells produced by other wells.

ment of the older horizons will be done in spite of curtailment of drilling due to the war. A few of the major oil companies operating in the district have inaugurated the practice of carrying their deeper wells to the Ellenburger. This practice should add to the control of the deeper horizons so a comprehensive study of these hitherto little known beds will be possible.

ACKNOWLEDGMENTS

The writers are indebted to R. B. Gilmore and D. V. Carter for information and assistance in preparing this paper.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift						Top Prod. Zone	Bottoms Prod. Wells				
72	0	3	42	Smithwick	Pen	L	Por	5,076 5,336	5,120 5,362	20	y	Ellenburger	5,418
73	0	20	y	Canyon	Pen	L	Por	2,600	2,630	10	y	Canyon	2,700
74	106	9	42	Ellenburger	Ord	L	Por	4,330	4,440	30	AC[3]	Ellenburger	4,494
75	1,132[2]	463	40	Strawn	Pen	LS	Por	3,500	4,000	25	AC	Ellenburger	4,494
76	0	36	y	Cisco	Pen	S	Por	1,313	1,328	12	N	Cisco	1,340
77	0	9	40	Cisco	Pen	S	Por	1,200	1,210	6	y	Cisco	1,482
78	4	5,757											
	1,242	6,297											
79	0	23	36	Cisco	Pen	S	Por	2,170 2,640	2,190 2,650	9 9	M	y	3,750
				Canyon	Pen	L	Por	3,190	3,210	15			
80	14	29	40	Cisco	Pen	S	Por	1,750	1,770	10	A	Ellenburger	4,381
				Strawn	Pen	LS	Por	3,750 4,025	3,770 4,065	20 40			
81	1	0	43	Ellenburger	Ord	L	Por	4,300	4,381	17	A	Ellenburger	4,381
82	2	0	43	Ellenburger	Ord	L	Por	3,627	3,635	8	A	Ellenburger	3,635
83	21	23	42	Cisco	Pen	S	Por	3,200	3,270	25	A	Ellenburger	6,717
				Canyon	Pen	L	Por	3,970	4,020	15			
				Strawn	Pen	S	Por	4,370	4,470	15			
84	0	13	40	Cisco	Pen	S	Por	1,450 1,800 2,040	1,490 1,890 2,060	y y 20	ML	y	2,867
85	3	3	41	Canyon	Pen	S	18	3,160 3,270	3,180 3,350	12 15	A	y	4,412
86	0	10	38	Cisco	Pen	S	Por	1,220 1,435 1,870 1,945	1,245 1,470 1,910 1,960	y	ML	y	2,671
87	0	2	y	y	Pen	S	Por	1,990 2,130	2,000 2,160	10 y	ML	Canyon	2,805
88	0	10	40	Cisco	Pen	S	Por	1,535	1,560	10	ML	Cisco	1,784
89	0	15	41	y	Pen	S	Por	1,310 1,628 2,296 2,430	1,330 1,640 2,360 2,440	20 12 y 10	ML	y	3,174
90	0	9	y	Cisco	Pen	S	Por	1,270	1,300	y	ML	y	2,725
91	1	5	36	Cisco	Pen	S	Por	y	1,902	y	y	y	3,370
				Canyon	Pen	L	Por	2,500 2,890	2,550 2,900	y 10			
92	9	19	y	Canyon	Pen	L	Por	3,015	3,025	10	A	Ellenburger	3,815
93	2	1	y	Ellenburger	Ord	L	Por	3,770	3,800	10	A	Ellenburger	3,815
94	0	8	y	Cisco	Pen	S	Por	2,190	2,220	15	y	y	2,863
95	0	1,489											
	53	1,659											
	1,781	14,868											

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[3] AC, anticline with accumulation modified by change in stratum.

TABLE 2.—*Summary of Drilling Operations in North Texas*

Discoveries, Extensions, and Important Wildcats Drilled during 1941

Field	County	Drilled By	Well Number and Farm	Survey
Pan-Taylor	Archer	King Oil Co.	Taylor No. 1	A. T. N. C. L.
Scotland	Archer	Shell Oil Co.	Coleman No. 4-A	A. T. N. C. L.
		Southern Petr. Exploration	L. F. Wilson No. 2	A. T. N. C. L.
		W. B. Hamilton	Cartwright No. 22	J. Webb
		C. H. Staley	Mangold No. 22	P. Castleman
		Jack Story	Wilson No. 1	A. T. N. C. L.
		Clark et al.	Parsons No. 1	Rob't. Meade
		Deep Oil Dev. & Snoddy Bros.	Clark No. 1	Clark-Plumb
		Golding & Cochran	M. J. Kunkel No. 1	B. B. B. & C.
		Sunray Oil Co.	C. W. Siebold No. 1	L. P. Jones
Seymour	Baylor	British-American	Cowan No. 1	T. & N. O.
Antelope (Miss.)	Clay	Shell Oil Co.	Henderson No. 9	T. E. & L.
Antelope (Deep)	Clay	Shell Oil Co.	Mullens No. 7-C	T. E. & L.
Burns-Browning	Clay	L. T. Burns	Southerland No. 1	J. H. Belcher
Joy	Clay	L. T. Burns	Wynn No. 1	H. Williams
Nebraska	Clay	Bridwell	Meyers No. 2	C. Thompson
New York City	Clay	Shell Oil Co.	Coleman No. 1-A	Calhoun Co. S. L.
Spring	Clay	Continental Oil Co.	Spring No. 1	H. & T. C.
Worsham	Clay	Gulf Oil Co.	Scaling No. 1	T. & N. O.
Bindel	Cooke	Texas Co.	Bindel No. 1	Hughes
		Texas Co.	Flietman No. 1	W. Simpson
Osburn	Cooke	J. Anderson	Osburn No. 1	B. Sullivan
Wilson	Cooke	Harvey Drilling Co.	Wilson-Ware No. 1	W. W. Crisp
		Burk Royalty Co.	Wilson No. 1	A. C. Bailey
		Harvey Drilling Co.	Wilson-Ware No. 1	W. W. Crisp
Benson	Montague	Benson & Benson	Seay No. 1	J. P. Owensby
		Superior Oil Co.	W. D. Seay No. 1-A	A. B. Morton
Bowers	Montague	United-Continental	Custers No. 2-B	J. McKnight
Chapman & McFarlin	Montague	Chapman & McFarlin	Fowler No. 1	J. W. Massie
Clingingsmith	Montague	Sinclair Prairie	Clingingsmith No. 1	Belcher Sub'd.
Seitz	Montague	Lesh & McCall	Davenport No. 5	J. Fitch
Stoneburg	Montague	Continental Oil Co.	Winder No. 1	Limestone Co. S. L.
Thomas	Montague	Shell Oil Co.	Thomas No. 1	Kaufman Co. S. L.
Turner	Montague	W. H. Gant et al.	Turner No. 1	E. T. R. R. Co.
	Montague	Gibson & Jennings	Howard No. 4	Kaufman Co. S. L.
K. M. A.	Wichita	Deep Oil Dev. Co.	Bradley No. 4-E	J. Beckman
		P. Sisk et al.	L. A. Sisk No. 2	Denton Co. S. L.
Consolidated	Wilbarger	Consolidated et al.	Ancell No. 4-B	H. & T. C.
Electra (Ellenburger)	Wilbarger	Magnolia Petr. Co.	Waggoner No. 65	H. & T. C.
Harrold	Wilbarger	Big Six Oil Co.	Schaffke No. 1	H. & T. C.
		Big Six Oil Co.	Cochran No. 1	M. K. & T.
		Big Six Oil Co.	Orr No. 1	H. & T. C.
Rock Crossing (Ellen)	Wilbarger	Phillips Petr. Co.	Waggoner-Bates No. 10	H. & T. C.

TABLE 2.—(*Continued*)

Discoveries, Extensions, and Important Wildcats Drilled during 1941

Producing Formation	Depth Completed	Total Depth	Surface Formation	Deepest Horizon Tested	Initial Production per Day	Choke or Bean, Fractions of an Inch	Remarks
					Oil, U. S. Bbls.		
Mississippi lime	4,927–4,949	5,055	Permian	Mississippi	59, 16 hr.	Pumping	One well only
Mississippi lime	5,550–5,560	5,850	Permian	Ellenburger	316, 2 hr.	Flowing	New pay, one producer, no failures
Strawn sand	4,016–4,032	4,032	Permian	Strawn	119	Flowing	New pay, 17 producers, one failure
Bend lime	5,149–5,164	5,211	Permian	Bend	8	Pumping	New pay
Cisco sand	1,728–1,735	1,735	Permian	Cisco	144	Pumping	New pay
Cisco sand	1,543–1,550	1,550	Permian	Cisco	52, 16 hr.	½″ choke	Three producers
Cisco sand	1,429–1,439	1,439	Permian	Cisco	10	Pumping	One well only
Cisco sand	815– 821	821	Permian	Cisco	5	Pumping	One well only
Bend lime	4,696–4,720	5,303	Permian	Mississippi			Dry and abandoned
Bend lime	5,001–5,012	5,050	Permian	Ellenburger			Dry and abandoned
Canyon	2,537–2,547	2,547	Permian	Canyon	58	Pumping	Extension
Mississippi lime	5,670–5,760	6,100	Per-Pen	Ellenburger	1203, 9 hr.	Flowing	One prod., no failures in Miss. lime
Bend lime	5,451–5,480	6,168	Per-Pen	Ellenburger	54	Pumping	New pay
Strawn sand	3,792–3,885	5,393	Per-Pen	Bend	60, 3 hr.	¾″ choke	New pay
Mississippi lime	5,905–5,967	6,088	Per-Pen	Mississippi	73, 3 hr.	Flowing	One producer, two failures
Bend lime	5,776–5,792	6,098	Per-Pen	Ellenburger	75, 3 hr.	½″ choke	Two producers, no failures in old field
Mississippi lime	6,158–6,283	6,837	Pennsylvanian	Ellenburger	138, 3 hr.	¾″ choke	Five producers, no failures
Bend lime	5,588–5,630	5,630	Pennsylvanian	Bend	104, 8 hr.	Flowing	One producer, no failures
Ellenburger dolomite	5,780–5,792	5,792	Pennsylvanian	Ellenburger	112, 3 hr.	Flowing	New pay
Strawn sand	1,885–1,896	1,896	Comanchean	Strawn	234	Pumping	Six producers, no failures
Ellenburger dolomite	3,242–3,247	3,247	Comanchean	Ellenburger	105	Flowing	Additional pay
Strawn sand	2,309–2,320	2,320	Comanchean	Strawn	10	Pumping	One producer, no failures
Strawn sand	2,221–2,227	2,227	Comanchean	Strawn	72	Pumping	Six producers, no failures
Strawn sand	2,065–2,086	2,086	Comanchean	Strawn	15	Pumping	Additional pay
Strawn sand	2,360–2,380	2,381	Comanchean	Strawn	96	Pumping	Additional pay
Bend conglomerate	5,752–5,762	5,789	Pennsylvanian	Bend	96, 8 hr.	Pumping	Three producers, no failures
Bend conglomerate	5,839–5,850	6,017	Pennsylvanian	Bend	116, 8 hr.	Flowing	Additional pay
Strawn sand	2,282–2,290	3,612	Pennsylvanian	Strawn	648	½″ choke	New pay
Strawn sand	4,840–4,857	6,008	Pennsylvanian	Ellenburger	96, 2½ hr.	¾″ choke	One producer, no failures
Bend conglomerate	6,119–6,131	6,131	Pennsylvanian	Bend	154, 3 hr.	Flowing	Five producers, no failures
Strawn sand	2,471–2,484	2,502	Comanchean	Strawn	250	¼″ choke	New pay
Bend lime	6,233–6,243	6,610	Comanchean	Viola	464	29/64″ choke	One producer, no failures
Strawn sand	3,023–3,045	4,646	Comanchean	Ellenburger	64	Pumping	One producer, no failures
Bend lime	6,222–6,234	6,248	Pennsylvanian	Bend	80, 5 hr.	Flowing	One producer, no failures
Strawn sand	3,930–3,940	4,514	Comanchean	Cambrian	187		One producer, three failures
Bend lime	3,963–3,992	4,495	Permian	Ellenburger	50, 3 hr.	½″ choke	New pay
Cisco sand	98– 100	100	Permian	Cisco	4	Pumping	One well only
Ellenburger dolomite	4,369–4,381	4,381	Permian	Ellenburger	102	Pumping	Three producers, no failures in Ellenburger
Ellenburger dolomite	2,992–2,996	3,001	Permian	Ellenburger	64	Flowing	Two producers, no failures in Ellenburger
Canyon sand	3,165–3,182	3,182	Permian	Canyon	122	Pumping	Six producers, no failures
Canyon lime	3,271–3,281	3,886	Permian	Strawn	38, 1 hr.	Flowing	Additional pay
Canyon lime	3,306–3,310	4,412	Permian	y	176	Pumping	Additional pay
Ellenburger	3,805–3,815	3,815	Permian	Ellenburger	94, 3 hr.	Flowing	Three producers, no failures in Ellenburger

Number of oil wells completed in 1941	1,213
Number of gas wells completed in 1941	2
Number of dry holes completed in 1941	365

Oil and Gas Production in North Central Texas in 1941

By H. W. Imholz*

The effect of new discoveries and development of other pools recently discovered is reflected in the increase in production from 586,000 bbl. during 1940 to 758,000 bbl. during 1941 in Coleman County. The States Oil Company's No. 1 Hudson, Coleman County, was the discovery well of the Silver field, with a total depth of 3540 ft.; initial production, 10,000,000 cu. ft. of dry gas and 60 bbl. of oil per day from the Gray sand, topped at 3482 ft. The first well drilled in the new Jim Ned field was the Merry Bros. and Perini No. 1 Greer, also in Coleman County. It had a total depth of 3937 ft. and an initial production of 152 bbl. of 42° gravity oil in 6 hr., through 1-in. choke, from Gray sand encountered from 3909 to 3937 feet.

J. E. Farrell's No. 1 Rose, Haskell County, was a new discovery, around which no additional wells have been drilled. Total depth was 3002 ft., plugged back to 2780 ft. to test an oil sand encountered from 2663 to 2685 ft., which when perforated with 76 shots at that depth was good for 85 bbl. of 40° gravity oil.

In Fisher County, General Crude drilled its No. 12 Flanagan to a total depth of 6746 ft. After plugging back to 4578 ft. to test a sand encountered from 4515 to 4528 ft. it was abandoned as a dry hole. The top of the Ellenburger was reported as 6094 feet.

Interest in Jones County continued unabated, largely through the development of the Wimberly pool in the southern part of the county, where five Cisco sands are producing. At present the pool has been defined on the south and the southwest. The structure has 170 ft. of closure; the lower limestone pays producing on top of the structure and the first pay encountered, the Akard sand, producing on the flanks of the structure.

Five deep wells were drilled in Stonewall County (H. and T.C. survey)—the Shell Oil Company's No. 1-A Patterson, in block D, with a total depth of 6827 ft., dry and abandoned; the Shell Oil Company's No. 1 Rutherford, block 1, with a total depth of 6239 ft., dry and abandoned; the Leader Oil Company's No. 1 Bilberry, block D, with a total depth of 5700 ft., dry and abandoned; Forest Development Company's No. 2 Boyd, block D, with a total depth of 4753 ft., dry and abandoned; and the Hunter et al. No. 1 Boyd, block D, total depth 4757 ft., dry and abandoned.

J. E. Farrell drilled his No. 1 Tipton south of a well that produced from a Strawn sand for some time, to a total depth of 5202 ft., where it was abandoned. The well is in the southwest corner of sec. 43, block 19, T. and P. survey, Nolan County.

Manuscript received at the office of the Institute April 30, 1942.

* Consulting Geologist, Abilene, Texas.

TABLE 1.—*Oil and Gas Production in North Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres, Oil	Total Oil Production, Bbl.	
				To End of 1941	During 1941
1	Bull Allcorn, *Brown*	1927	100	136,796	2,900
2	Byler, *Brown*	1926	290	86,267	8,997
3	Byrd, *Brown*	1920	250	407,389	1,509
4	Childress, *Brown*	1927	180	946,187	35,803
5	Clark-Buffalo, *Brown*	1927	460	821,687	14,763
6	Cross Cut, *Brown*	1921	2,300	6,417,878	90,214
7	Fry, *Brown*	1925	940	7,903,502	47,454
8	George, *Brown*	1927	200	844,932	34,098
9	Smith-Ellis, *Brown*	1926	450	2,394,635	49,351
10	Stover, *Brown*	1926	1,500	7,444,732	131,949
11	Others, *Brown*		5,595	2,623,859	53,997
12	Total *Brown County*		12,265	30,806,864	471,035
13	Baum, *Callahan*	1925	500	886,639	6,451
14	Hatchett, *Callahan*	1927	375	1,450,719	29,162
15	Isenhour, *Callahan*	1923	600	2,261,478	38,898
16	Moutray, *Callahan*	1926	400	2,629,230	60,651
17	Others, *Callahan*		9,515	7,652,973	226,893
18	Total *Callahan County*		11,390	14,881,039	362,055
19	Burkett, *Coleman*, Shallow	1924	850	2,454,636	64,067
20	Deep	1930	200	712,523	11,822
21	Dibrell, *Coleman*	1927	170	491,734	30,969
22	Eastland, *Coleman*	1928	270	2,104,565	35,158
23	Jennings, *Coleman*	1927	135	498,356	14,622
24	Overall, *Coleman*	1926	200	1,342,978	41,524
25	Santa Anna, *Coleman*	1922	150	465,878	2,967
26	Stewardson, *Coleman*	1930	200	439,223	11,841
27	Others, *Coleman*		985	2,885,596	545,784
28	Total *Coleman County*			11,395,489	758,754
29	Others, *Comanche*			1,693,488	97,009
30	Desdemona, *Eastland, Erath*	1918	6,175	23,422,608	139,801
31	Hilburn, *Eastland*	1919	400	1,128,753	8,837
32	Mangum, *Eastland*	1922	300	923,779	22,213
33	Pioneer, *Eastland*	1919	1,400	5,621,365	54,711
34	Others, *Eastland*			67,554,198	669,724
35	Total *Eastland County*			75,228,095	755,485
36	Howard, *Fisher*	1934	100	103,331	10,096
37	Royston, *Fisher*	1928	2,900	11,220,474	491,977
38	Rotan (Robinson), *Fisher*	1936	640	1,173,735	145,247
39	Rotan, Bennett, *Fisher*	1937	80	60,926	9,219
40	Total *Fisher County*			12,558,466	656,539
41	Others, *Haskell*			191,613	13,082
42	Akard, *Jones*	1938	200	185,173	117,098
43	Avoca, Griffin, *Jones*	1938	640	1,685,823	463,998
44	Avoca, Olander, *Jones*	1936	640	1,819,208	462,347
45	Dorsey, Hawley, *Jones*	1935	600	3,152,159	121,395
46	Guitar Hawley, *Jones*	1936	400	790,001	40,290
47	Irvin, Noodle Creek, *Jones*	1937	500	280,539	80,884
48	Jennings, *Jones*	1934	160	598,501	12,839
49	Lewis, *Jones*	1936	800	1,506,931	396,840
50	Noodle Creek, *Jones*	1927	1,030	7,059,898	180,760
51	Sayles, *Jones*	1932	640	2,087,352	325,918
52	Sandy Ridge, *Jones*	1935	450	367,893	62,496
53	Steffens, *Jones*	1937	640	591,920	227,332
54	Others, *Jones*			415,829	142,961
55	Total *Jones County*		6,700	20,541,227	2,635,153
56	Bluff Creek, *Shackelford*	1930	940	3,530,246	217,303
57	Cook, *Shackelford*	1925	1,460	17,108,400	588,670
58	Frye, *Shackelford*	1925	115	337,099	6,441
59	Hope, *Shackelford*	1923	220	1,361,006	52,374
60	Ibex, *Shackelford*	1921	1,240	2,480,828	20,455
61	Ivy, *Shackelford*	1937	700	1,525,639	438,567
62	Newell, *Shackelford*	1925	640	916,563	42,982
63	Simmons-Harvey, *Shackelford*	1925	160	420,569	23,393
64	Tannehill, *Shackelford*	1927	300	2,536,804	99,994
65	Others, *Shackelford*			12,125,171	603,138
66	Total *Shackelford County*			42,342,325	2,093,317
67	Stephens County			128,343,104	1,163,449
68	Stonewall County			126,980	36,884
69	Taylor County			531,143	128,863
70	Throckmorton County			3,566,077	175,089
71					
72					

TABLE I.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells, End of 1941	Character of Oil, Gravity A.P.I. at 60°F., Weighted Average	Producing Formation				
	Producing Oil[c]		Name	Age[e]	Character[f]	Depth, Avg. Ft.	Structure[h]
1	11	38	Fry	Pen	S	1,150	ML, N
2	24	39	Fry	Pen	S	1,300	ML, N
3	10	37	Bend	Pen	L	2,450	A
4	112	35	Childress	Pen	S	800	ML, N
5	36	42	Fry	Pen	S	1,150	ML, N
6	149	40	Cross Cut	Pen	S	1,200	ML, M
7	100	42	Fry	Pen	S	1,300	ML, N
8	30	39	Fry	Pen	S	1,300	ML, N
9	37	41	Fry	Pen	S	1,300	ML, N
10	159	41	Blake	Pen	S	1,200	ML, N
11							
12							
13	15	39	Cross Plains	Pen	S	1,700	ML, N
14	94	38	Moutray	Pen	S	400	ML, N
15	136	37	Isenhour	Pen	S	700	ML, N
16	77	37	Moutray	Pen	S	500	ML, N
17	980						
18	1,302						
19	173	34	Burkett	Pen	S	400	ML, N
20	19	41	Cross Cut	Pen	S	1,550	ML, N
21	14	42	Gwinnup	Pen	S	1,900	ML, N
22	28	42	Gwinnup	Pen	S	2,000	ML, N
23	26	39	Fry	Pen	S	1,950	ML, N
24	12	42	Strawn	Pen	S	2,000	A
25	10	39	Fry	Pen	S	1,500	ML, N
26	15	39	Fry	Pen	S	1,450	ML, N
27	50						
28							
29	138						
30	66		Desdemona	Pen	S	2,750	A
31	3	37	Bend	Pen	L	3,100	MN
32	35	38	Strawn	Pen	S	1,200	N
33	50	41	Caddo	Pen	L	2,450	AF
34	359						
35							
36	1		Saddle Creek	Pen	L	3,670	ML, N
37	117	39	Camp Colorado	Pen	L	3,100	A
38	35	38	Camp Colorado	Pen	L	3,500	MN
39	1	39		Pen	L	3,600	MN
40							
41							
42	11	39	Bluff Creek	Pen	S	2,200	A
43	64	39	Strawn-Canyon	Pen	L	3,200	A
44	54	39	Strawn-Canyon	Pen	L	3,200	A
45	79	39	Six Cisco	Pen	S	1,900–2,300	A
46	67	37	Cook	Pen	L	2,000	A
47	10	39	Four Cisco	Pen	L, S	2,350–3,000	A
48	18	39	King	Pen	S	2,040	A
49	87	39	Bluff Creek	Pen	S	1,900	ML, N
50	83	38	Camp Colorado	Pen	L	2,500	MC, A
51	50	41	Cook	Pen	S	1,950	N
52	21	37	Bluff Creek	Pen	S	1,900	N
53	30	37	Bluff Creek	Pen	S	1,900	ML, N
54							
55							
56	214	37	Bluff Creek	Pen	S	1,600	N
57	327	37	Cook	Pen	S	300	ML, N
58	38	35	Frye	Pen	S	450	ML, N
59	39	37	Hope	Pen	S	1,500	ML, N
60	17	39	Caddo	Pen	L	3,500	N
61	72	39	Strawn-Canyon	Pen	L	1,900–3,200	A
62	85	37	Tannehill	Pen	S	1,100	ML, N
63	19	39	Bluff Creek	Pen	S	1,700	N
64	84	38	Tannehill	Pen	S	1,150	ML, N
65							
66							
67							
68							
69							
70							
71							
72							

[c] Footnotes to column heads and explanation of symbols are given on page 250.

Oil and Gas Development in the Texas Panhandle in 1941

By Henry Rogatz* and H. W. McCue†

Oil.—In the Texas Panhandle, during the year of 1941, 647 oil wells were drilled with a total daily initial production of 133,435 bbl.—that is, 145 more oil wells than in the previous year, with a decrease in total daily production of 5752 bbl. On Dec. 31, 1941, a daily allowable of 116,766 bbl., which was an increase of 27 per cent over 1940, was assigned to the field to be produced from 5182 wells. The total amount of oil produced for the year was 27,904,846 bbl., making a cumulative total of 404,657,324 bbl. during the past 20 years.

Gas.—During the year, 52 gas wells were drilled, having a combined open flow of 2.62 billion cu. ft. per day—that is, 40 less than the number of wells drilled in 1940, with an increase in the open flow of 217,100,000 cu. ft. per day. The gas

Table 1.—*Oil and Gas Production in the Texas Panhandle*

Line Number	County	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	During 1941		End of 1941			Number of Wells	
										Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
1	Carson	1921	19,570	247,194	38,929,174	3,336,866			1,016	53	12	y	542	347	y	y
2	Gray	1925	59,805	227,127	184,754,144	12,861,106			2,838	258	20	y	2,275	232	y	y
3	Hansford	1937	0		0	0			1	0	0	y	0	0	0	0
4	Hartley	1928	0	29,491	0	0			4	0	0	y	0	4	0	0
5	Hutchinson	1922	64,793	217,071	155,342,146	9,921,193			2,987	308	21	y	1,769	356	y	y
6	Moore	1926	640	432,130	5,138,284	171,605			457	36	0	y	21	416	y	y
7	Potter	1919	0	144,786	33,822	0			54	0	0	y	0	45	0	0
8	Sherman	1938	0		0	0			4	0	0	y	0	0	y	y
9	Wheeler	1925	8,250	153,768	20,459,754	1,614,076			811	43	4	y	407	347	y	y
10	Total		153,058	1,451,567	404,657,324	27,904,846	10,055,451	688,195,955	8,172	698	57	y	5,014	1,747	y	y

[b] Footnotes to column heads and explanation of symbols are given on page 250.

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* Consulting Geologist, Amarillo, Texas.

† Columbian Fuel Corporation, Amarillo, Texas.

production for the year was 688,195,955,000 cu. ft. and the total gas removed from the ground during the past life of the field was about 10 trillion cu. ft. No additional gas acreage was added to that listed in 1940.

Pipe-line Gas.—The pipe-line companies withdrew 281,251,481,000 cu. ft. of gas (a daily average of 770,552,000 cu. ft.). The total yearly withdrawals by pipe line increased 17,470,285,000 cu. ft. from those of 1940.

Natural Gasoline.—Throughout the year, 38 gasoline-extraction plants processed 1,489,746,000 cu. ft. per day, a total of 543,757,386,000 cu. ft. for the year. This gas yielded 320,478,396 gal. of natural gasoline. The total daily capacity of all the plants is 2,434,400,000 cu. feet.

Carbon Black.—Twenty-nine carbon black plants operated during 1941, burning 289,189,086,000 cu. ft., or a daily amount of 804,138,000 cu. ft., and producing approximately 425,000,000 lb. of carbon black for the year.

Refineries.—Runs to the six operating refineries for the year of 1941 amounted to approximately 17,500,000 bbl.—a daily average of 47,945 bbl., or an increase of 7159 bbl. per day over 1940.

Storage.—The oil in storage decreased 173,083 bbl., from 2,005,655 to 1,832,572 bbl. The total storage capacity at the end of the year was 14,468,500 barrels.

New Developments.—The Stinnett pool, in western Hutchinson County, was extended one mile northwest, adding about 600 proven acres.

The Huber Carbon Co. development work extended the Borger pool, Hutchinson County, to the southwest, adding 1280 additional proven acres. Production is

TABLE 1.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
	Initial	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft. Top Prod. Zone	Depth, Avg. Ft. Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	430	39	0.06	Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen Pen	D, DA LA GW	x	3,000	3,040	40	AF	Granite wash (E Zone)	y
2	430	39	0.04	Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen Pen	D, DA LA GW	x	3,100 2,850	3,150 2,880	50 30	AF AF	Granite wash (E Zone)	y
3	430			Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen Pen	D, DA LA GW	x	x	x	x	AF	Big Lime series (Wichita)	3,311
4	430			Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen Pen	D, DA LA GW	x	x	x	x	AF	Granite wash (E Zone)	y
5	430	35	0.08	Big Lime series (Wichita)	Per-Pen	L	x	2,800–3,200	2,840–3,240	40	AF	Arbuckle	5,333
6	430	31	0.08	Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen	D GW	x	3,400	x	x	AF	Arbuckle	8,013
7	430	y	y	Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen	GW	x	x	x	x	AF	Granite wash (E Zone)	y
8	430			Big Lime series (Wichita)	Per-Pen	D	x	x	x	x	AF	Arbuckle	5,138
9	430	37	0.04	Big Lime series (Wichita) Granite wash (Cisco)	Per-Pen	D GW	x	2,400	2,430	30	AF	Arbuckle	2,957
10													

from a very porous arkose and white dolomite.

A new pool was opened 5 miles southwest of the town of LeFors, in Gray County, known as Little Seminole. This discovery added 480 acres of dolomite production.

Wildcats.—Eight wildcats were completed, none of which discovered oil or gas in commercial quantities. They were distributed among the following counties: Hale, 1; Hemphill, 1; Bailey, 1; Motley, 1; Sherman, 1; Potter, 3.

The Indian Territory Illuminating Oil Co. completed a third test on the Stratford dome in southwest Sherman County. Total depth of 4014 ft. was reached, placing the bottom of the hole in the upper part of the Mississippian. The well was plugged back for gas in the lower Permian.

Oil and Gas Development in South Central Texas for 1941

By William H. Spice, Jr.,* Member A.I.M.E.

The area on which oil and gas development is reported covers 30 counties, which are included in the Texas Railroad Commission's District No. 1. This area not only includes the old established Balcones fault-line group of producing fields but also includes the southwest extension of this trend and some of the deeper Wilcox (Eocene) exploratory development. (Fig. 1.)

In the old Balcones fault-line zone, three new fields were discovered during 1941. These fields are comparatively small, producing from Dale limestone or Austin chalk. No new fields were discovered during the year in the Edwards (Lower Cretaceous) limestone horizon. One new shallow field was discovered in the Reklaw (Eocene) sand horizon and, in the southwestern part of the district, one oil field and one gas field were discovered in the Navarro (Upper Cretaceous) sand horizon. An extremely important extension was made to the one producing Wilcox (Eocene) field of the district in the Washburn Ranch field of La Salle County.

The district produced 6,650,357 bbl. during 1941, which was a 12 per cent decrease under production for 1940. Approximately 4,954,000 bbl. of this total production was produced by the three Edwards limestone fields, Luling, Salt Flat and Darst Creek, the remaining production coming from the other 43 active fields in the district. In all, 3694 wells were producing at the end of 1941, compared with 3559 wells at the end of the previous year. During the year, 139 new producing wells were completed and 29 wells were abandoned in the producing fields. The increase in producing wells represents an increase in new wells over abandonments in these fields, together with a decrease in wells temporarily shut down as of the end of 1941. The majority of production drilling was carried on in the following fields; Bee Creek, Chicon Lake, Elm Creek, Gas Ridge, Pearsall and Tenney Creek. Approximately 250 wells were drilled during 1941, of which 110 were exploratory wells completed as failures throughout the district.

Considerable exploratory work was continued during 1941 along the Wilcox trend. Geophysical work employing various types of geophysical methods and leasing activity was continued along this trend, particularly by the major companies. The significance of this activity is apparent from the successful extension and development in the Washburn field of La Salle County, where several well-developed gas-and-oil producing horizons have been developed in the lower Wilcox section between 5100 and 5600 ft. as noted in the following paragraphs. Continued exploratory activity along this general trend as far as present conditions will permit is predicted for 1942.

New Fields

Elgin Field, Bastrop County.—No. 1-A Hiram Walker, Marts and Beaven, Inc., discovery well of the Elgin field, was completed on Apr. 22, 1941, in broken Austin chalk from 2820 to 2840 ft., pumping 105 bbl. per day, 36.8°A.P.I. gravity. The well apparently is producing from a crevice in

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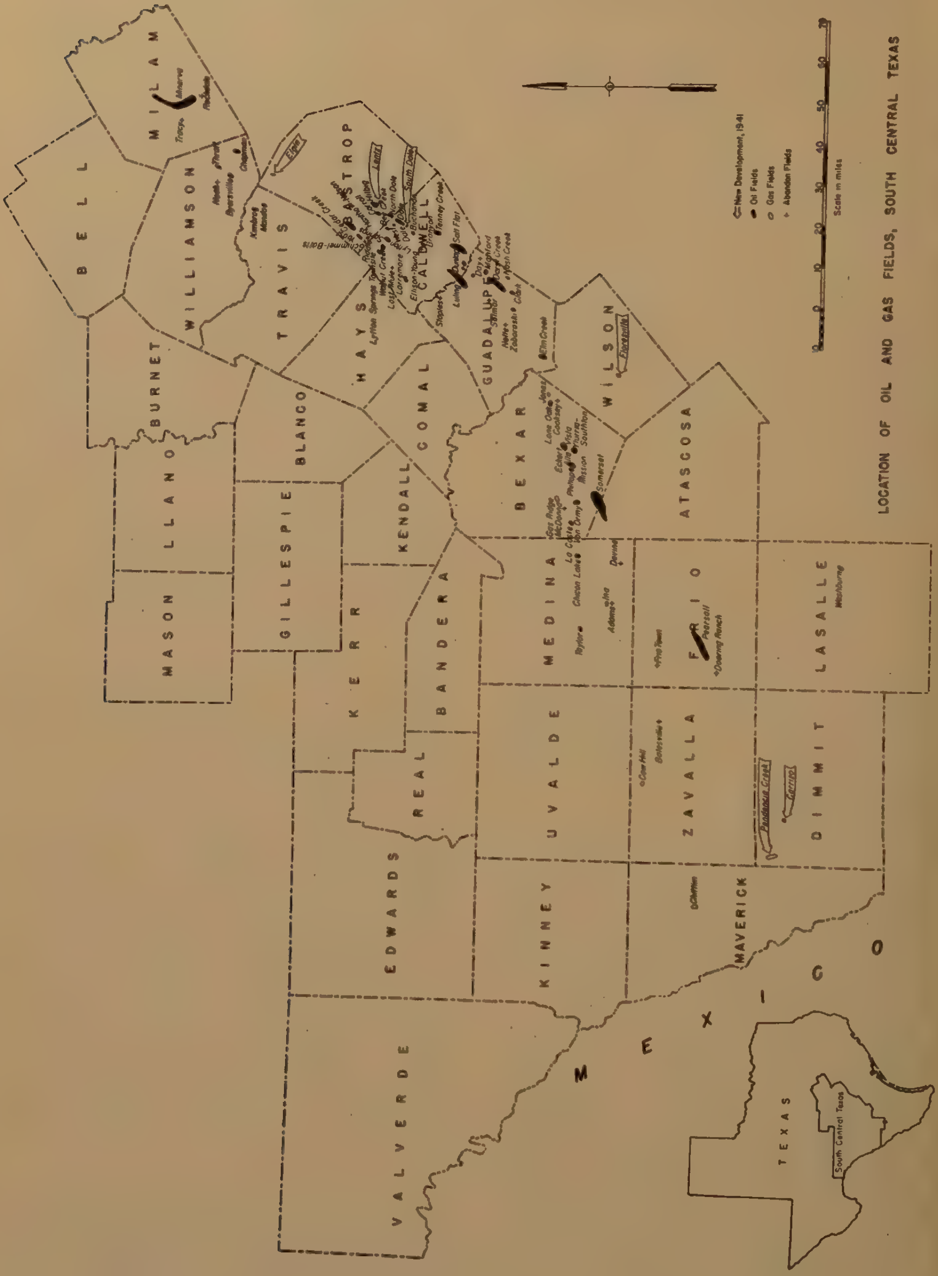
* Consulting Geologist, San Antonio, Texas.



LOCATION OF OIL AND GAS FIELDS, SOUTH CENTRAL TEXAS

FIG. 1.

the Austin chalk, after being drilled into the Edwards limestone and plugged back and acidized in the producing horizon. Efforts to date to extend the field have all been failures.

Lentz Field, Bastrop County.—Furlong and Thompson's No. 1 O. B. Lentz, discovery well of the Lentz field, was completed on July 14, 1941, from Dale limestone at 2226 to 2244 ft., flowing 497 bbl. per day, ¼-in. choke, 110 lb. tubing pressure, 250 lb. casing pressures, 36°A.P.I. gravity, after being acidized with 2000 gal. Credit for this discovery is due to subsurface geology along trend to the northeast of the old Red Rock prospect. At the end of the year, three producing oil wells had been completed and the field had produced 5660 barrels.

South Dale Field, Caldwell County.—Ogden and Riddle Oil Company's No. 1 R. P. Copeland, 2 miles southeast of the Dale field, was completed during October 1941 from Dale limestone and Austin chalk, from 2018 to 2420 ft. Considerable mechanical difficulty has been experienced and the well had no production credited to it as of the end of the year. The discovery is the result of subsurface geology and trend drilling and is significant in that it adds prospective acreage to the Dale producing area.

Pendencia Creek, Dimmit County.—Wellington Oil Company's No. 1-B D. J. Sullivan, about 12 miles northwest of Carrizo Springs, was completed on Dec. 5, 1941, from upper Navarro sand, 1084 to 1090 ft., for an estimated open flow of 1,000,000 cu. ft. of gas, 525 lb. closed-in pressure. This well, in drilling to a total depth of 3005 ft., encountered several sands in the Navarro section showing oil, which could not be successfully completed as productive. The discovery is the result of surface geology and is significant because of its location on the extension of the Chittim Arch, a regional structural feature of Maverick County. As of the end of the year, a second well has been located 2 miles to the south on the same structure.

Floresville, Wilson County.—H. J. Baker's No. 1 John Myers, one mile northeast of Floresville, was completed on Sept. 19, 1941, from sand 635 to 640 ft. in the Reklaw formation, pumping 3 bbl. per day. To date, four additional wells have been drilled in the immediate area without being successfully completed as producers. The significance of this discovery is that it is the first production in the district from the Reklaw formation of the Claiborne group (Eocene).

EXTENSIONS

Washburn, La Salle County.—Quintana Petroleum Company's No. 4 (1-B) Washburn (South Texas Syndicate), about one mile southwest of the discovery well of the Washburn field, was dual-completed on Nov. 6, 1941, from lower Wilcox sand 5509 to 5582 ft., flowing 405 bbl. per day, ¼-in. choke, 525 lb. tubing pressure, after drilling to a total depth of 5725 ft. The 5½-in. casing was cemented at 5723 ft. and the oil well produced through 2-in. tubing with packer, through casing perforations 5530 to 5550 ft. The dual completion was accomplished by also perforating the casing in an upper gas sand from 4820 to 4850 ft. and producing as a gas well through the casing. This gas well tested 20,000,000 cu. ft. of gas, ¼-in. choke, 1130 lb. pressure, 1840 lb. closed-in pressure. A third producing oil sand also was encountered in this well from 5136 to 5155 ft. but to date no completions have been made in it. The significance of this extension is important not only from the standpoint of the occurrence of several thick producing sand horizons in the lower Wilcox of this area, but also from the successful dual completion from sands about 700 ft. apart, with an adequate gas supply for the continued development of the field. At the end of the year, a second well (No. 5), 500 ft. north of this well, was

TABLE 1.—*Oil and Gas Production in South Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941	
										During 1941		End of 1941			Number of Wells	
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift
1	Alta Vista,[1] *Bexar*	1912	300	0	124,097	3,341	0	0	41	0	0	0	41	0	0	41
2	Bee Creek, *Caldwell*	1940	280	0	159,104	112,054	0	0	28	15	0	0	28	0	0	28
3	Branyon, *Caldwell*	1930	900	0	2,748,032	262,966	0	0	185	0	1	0	152	0	0	152
4	Buchanan, *Caldwell*	1928	250	0	428,328	26,048	0	0	41	0	5	0	23	0	0	23
5	Burdette Wells, (N. E. Luling), *Caldwell*	1936	200	0	58,421	1,304	0	0	12	0	0	0	2	0	0	2
6	Byersville,[2] *Williamson*	1933	370	0	547,768	22,953	0	0	47	0	0	0	41	0	0	41
7	Carrizo, *Dimmit*	1941	20	0	5,218	5,218	0	0	1	1	0	0	1	0	1	0
8	Carroll, *Bastrop*	1932	100	0	101,547	0	0	0	9	0	1	7	0	0	0	0
9	Cedar Creek, *Bastrop*	1932	100	0	285,394	10,237	0	0	13	0	2	0	8	0	0	8
10	Chapman, *Williamson*	1928	450	0	4,354,016	65,983	0	0	70	0	0	0	70	0	0	70
11	Chicon Lake, *Medina*	1920	450	0	79,040	16,437	0	0	82	16	0	0	81	0	0	81
12	Chriesman,[3] *Burleson*	1938	10	0	19,310	0	0	0	1	0	1	0	0	0	0	0
13	Dale, *Caldwell*	1927	280	0	1,548,019	47,226	0	0	58	4	1	0	52	0	0	52
14	West	1932	240	0		15,263	0	0								
15	North (Bateman)	1941	320	0		14,984	0	0	12	0	2	0	4	0	0	4
16	South	1937	10	0	0	0	0	0	1	1	0	1	0	0	0	0
17	Darst Creek, *Guadalupe*	1928	1,920	0	50,496,516	1,787,515	0	0	362	5	0	0	350	0	6	344
18	Darst Creek Extension (Clark), *Guadalupe*	1935	200	0	379,623	13,892	0	0	11	0	3	0	5	0	0	5
19	Day,[3] *Guadalupe*	1940	20	0	575	0	0	0	2	0	2	0	0	0	0	0
20	Dunlap, *Caldwell*	1930	120	0	355,456	13,789	0	0	14	0	3	0	7	0	0	7
21	Dunlay,[3] *Medina*	1938	30	0	1,988	0	0	0	1	0	0	0	0	0	0	0
22	Eckert, *Bexar*	1927	850	0	911,279	29,311	0	0	121	0	0	0	111	0	0	111
23	Elgin, *Bastrop*	1941	10	0	3,565	3,565	0	0	1	1	0	0	1	0	0	1
24	Elm Creek (Lavernia), *Guadalupe*	1939	400	0	24,497	18,196	0	0	47	16	0	0	31	0	0	31
25	Floresville, *Wilson*	1941	5	0	0	0	0	0	1	1	0	1	0	0	0	0
26	Gas Ridge, *Bexar*	1912	150	150	83,771	12,654	*y*	*y*	128	39	0	0	63	*y*	0	63
27	Hilbig, *Bastrop*	1932	260	0	1,633,390	81,914	0	0	12	0	0	0	12	0	11	1
28	Jones, *Bexar*	1921	20	0	2,717	566	0	0	3	0	0	1	2	0	0	2
29	Kimbro, *Travis*	1935	40	0	3,719	250	0	0	4	0	0	1	3	0	0	3
30	La Coste (Fairfield), *Bexar*	1939	40	10	3,837	932	*y*	*y*	5	0	0	1	1	0	0	1
31	Larremore, *Caldwell*	1927	80	0	341,667	16,807	0	0	13	0	0	2	10	0	0	10
32	Lentz, *Bastrop*	1941	30	0	5,660	5,660	0	0	3	3	0	0	3	0	1	2
33	Lone Oak,[3] *Bexar*	1934	10	0	4,485	0	0	0	1	0	1	0	0	0	0	0
34	Luling, *Caldwell and Guadalupe*	1921	2,200	0	76,823,674	1,923,780	0	0	606	0	0	1	582	0	0	582
35	Lytton Springs, *Caldwell*	1925	1,360	0	8,584,943	95,890	0	0	157	0	2	0	137	0	0	137
36	Manda, *Travis*	1935	40	0	25,269	884	0	0	3	0	0	0	1	0	0	1
37	Manford, *Guadalupe*	1923	40	0	408,150	6,452	0	0	1	0	0	0	1	0	0	1
38	Minerva-Rockdale, *Milam*	1921	4,250	0	3,677,689	77,173	0	0	423	4	4	0	419	0	0	419
39	Nash Creek,[4] *Guadalupe*	1936	10	0	46,535	0	0	0	1	0	1	0	0	0	0	0
40	Pearsall, *Frio*	1933	800	0	1,501,739	299,616	0	0	34	7	0	0	34	0	11	23
41	Philtop, *Bexar*	1938	40	0	7,799	1,216	0	0	8	0	0	0	4	0	0	4
42	Riddle, *Bastrop*	1938	50	0	75,279	14,164	0	0	7	0	0	0	3	0	0	3
43	Salt Flat, *Caldwell*	1928	1,300	0	42,507,250	1,242,052	0	0	298	0	0	5	273	0	1	272
44	Somerset, *Atascosa and Bexar*	1912	11,390	0	10,913,121	178,193	0	0	915	0	0	23	851	0	14	837
45	Southton-Yturria, *Bexar*	1921	650	0	672,955	19,417	0	0	103	0	0	0	103	0	0	103
46	Spiller, *Guadalupe*	1938	30	0	17,473	4,538	0	0	6	0	0	0	3	0	0	3
47	Taylor-Ina, *Medina*	1922	380	0	155,726	2,766	0	0	16	0	0	0	8	0	0	8
48	Tenney Creek, *Caldwell*	1940	150	0	96,271	92,083	0	0	24	22	0	0	24	0	7	17
49	Thrall, *Williamson*	1914	475	0	2,482,296	21,870	0	0	27	0	0	0	21	0	0	21
50	Von Ormy, *Bexar*	1933	650	0	266,653	28,795	0	0	108	0	0	2	106	0	0	106
51	Walnut Creek, *Caldwell*	1938	50	0	7,172	685	0	0	3	0	0	0	1	0	0	1
52	Washburn, *LaSalle*	1940	40	20	25,861	15,355	*y*	*y*	3	2	0	0	3	1	2	1
53	Yost, *Bastrop*	1928	120	0	918,148	6,580	0	0	6	0	0	0	4	0	0	4
54	Zoboroski, *Guadalupe*	1935	180	0	229,225	19,269	0	0	14	0	0	0	14	0	0	14
	GAS ONLY															
55	Adams (Medina), *Medina*	1926	0	2,000	0	0	*y*	*y*	58	0	0	0	0	13	0	0
56	Chittim, *Maverick*	1929	0	100[5]	62,045	10,514	*y*	*y*	19	1	0	0	0	5	0	0
57	Pendencia Creek, *Dimmit*	1941	0	20	0	0	*y*	*y*	1	1	0	0	0	1	0	0
58	Total		32,670	2,300	214,216,312	6,650,357			4,171	139	29	45	3,694	20	54	3,640

[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Includes Dupree. [2] Includes Mathews and Noack. [3] Abandoned 1940. [4] Abandoned 1941. [5] Gas and distillate.

TABLE I.—(*Continued*)

Line Number	Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
										Depth, Avg. Ft.					
	Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	*x*	*y*		18	*y*	Navarro sands	CreU	S	15–20	220	250	20	F	Travis Peak	4,535
2	*y*	*y*		39	*y*	Dale lime, serpentine	CreU	LP	Por	2,050	2,240	*y*	Intn	Austin chalk	2,436
3	*x*	*y*		37	0.8	Austin chalk, Edwards lime	CreU & L	L	Por	1,816	2,275	*y*	F	Edwards lime	2,450
4	*x*	*y*		39	0.2	Serpentine	CreU	P	12	1,750	2,075	*y*	Intn	Edwards lime	2,483
5	200	*y*		28	0.8	Edwards lime	CreL	L	Crev	2,210	2,235	15	F	Edwards lime	2,420
6	*x*	*y*	RP	37	0.2	Serpentine	CreU	P	20	850	900	*y*	Intn	Edwards lime	2,000
7	*y*	*y*		30	*y*	Navarro sand	CreU	S	26	2,294	2,298	4	MC	Taylor	3,120
8	*x*	*y*		36	*y*	Serpentine	CreU	P	12	2,300	2,378	78	Intn	Edwards lime	2,919
9	100	*y*		35	0.2	Serpentine	CreU	P	15–20	1,650	1,700	50	Intn	Edwards lime	2,300
10	400	*y*		36	0.2	Serpentine	CreU	P	20	1,750	1,915	20	Intn	Edwards lime	3,226
11	*x*	*y*		21	0.1	Navarro sands	CreU	S	15	260	750	20	D	Edwards lime	1,725
12	*x*	*y*		34.5	*y*	Edwards lime	CreL	L	Por	6,167	6,182	*y*	F	Edwards lime	6,340
13	150	*y*		37	0.2	Dale lime, serpentine	CreU	LP	15	1,915	2,250	30	Intn	Edwards lime	2,661
14															
15															
16	*y*	*y*		*y*	*y*	Dale lime, Austin chalk	CreU	L, C	Por	2,018	2,420	*y*	F	Austin chalk	2,420
17	350	*y*		36	0.8	Edwards lime	CreL	L	Por	2,650	2,700	30	F	Travis Peak	5,509
18	200	*y*		33.6	0.5	Austin chalk	CreU	C	5–25	2,375	2,450	100	F	Edwards lime	3,200
19	*x*	*x*		36	*y*	Austin chalk, Buda lime	CreU & L	CL	Por	2,337	2,685	*y*	F	Edwards lime	2,830
20	400	*y*		36	0.6	Austin chalk	CreU	C	Crev	2,300	2,375	15	F	Edwards lime	2,420
21	*y*	*y*		21	*y*	Serpentine	CreU	P	*y*	542	714	*y*	Intn	Austin chalk	851
22	*y*	*y*		34	0.3	Navarro sands	CreU	S	16	620	790	10	F	Edwards lime	1,590
23	*y*	*y*		36	*y*	Austin chalk	CreU	C	Crev	2,820	2,840	20	F	Edwards lime	3,352
24	*y*	*y*		41	*y*	Navarro sands	CreU	SH	Por	700	850	*y*	T	Navarro	850
25	*y*	*y*		*y*	*y*	Reklaw sand	Eoc	S	*y*	635	640	*y*	*y*	Reklaw	662
26	*x*	*y*		22	0.4	Navarro sands	CreU	S	15–20	230	760	15	A	Travis Peak	3,460
27	1,240	*y*	PM	37	0.2	Serpentine	CreU	P	12	2,450	2,575	50	Intn	Edwards lime	3,250
28	*x*	*y*		*y*	*y*	Navarro sands	CreU	SH	Por	600	*x*	*x*	T	Edwards lime	2,008
29	*x*	*y*		36.5	*y*	Serpentine	CreU	P	Por	660	670	*y*	Intn	Edwards lime	1,280
30	*x*	*y*		28	*y*	Anacacho lime	CreU	L	Por	1,150	1,190	*y*	N	Austin chalk	1,227
31	*x*	*y*		23	0.6	Edwards lime	CreL	L	30	1,285	1,315	35	F	Travis Peak	3,360
32	*y*	*y*		36	*y*	Dale lime	CreU	L	Por	2,226	2,244	18	F	Austin chalk	2,453
33	*x*	*x*		33.4	*y*	Navarro-Taylor	CreU	SH	Por	1,480	1,620	18	F	Edwards lime	2,250
34	1,500	*y*		27	0.9	Edwards lime	CreL	L	25	2,100	2,200	50	F	Schist	7,859
35	1,250	*y*		37.5	0.4	Serpentine	CreU	P	12	1,535	1,820	300*x*	Intn	Edwards lime	2,050
36	*x*	*y*		34	0.4	Serpentine	CreU	P	15–25	720	757	*x*	Intn	Taylor	850
37	1,250	*y*		37	0.9	Austin chalk	CreU	C	Crev	2,260	2,310	30	F	Edwards lime	2,800
38	*x*	*y*		38	0.2	Navarro sands	CreU	SH	Por	600	1,700	15	T	Glenrose	5,000
39	340	*y*		27	0.8	Taylor marl	CreU	SL	Por	2,570	2,585	15	F	Edwards lime	3,342
40	1,500	*y*		27 38	*y* *y*	Navarro sand Austin chalk	CreU CreU	S C	Por Por	3,920 5,400	3,950 5,850	15 *x*	N	Travis Peak	10,050
41	*x*	*y*		23	*y*	Austin chalk	CreU	C	Por	1,100	*y*	*y*	F	*y*	*y*
42	*x*	*y*		39	*y*	Austin chalk, serpentine	CreU	CP	Por	1,667	1,747	*y*	F	Austin chalk	1,777
43	1,200	*y*		36	0.6	Edwards lime	CreU	L	30	2,670	2,740	25	F	Edwards lime	2,918
44	300	*y*		36	1.4	Navarro-Taylor sands	CreU	SH	22	1,200	2,100	30	TF	Travis Peak	5,311
45	*x*	*y*		32	*y*	Navarro sands	CreU	S	16	600	800	10	F	Glen Rose	3,850
46	*x*	*y*		38.3	*y*	Buda lime	CreL	L	Por	2,012	2,298	*y*	F	Edwards lime	2,382
47	*x*	*y*		18	0.5	Navarro sands	CreU	S	15–20	290 940	400 960	15 10	FT	Edwards lime	2,048
48	*x*	*y*		35.5	*y*	Austin chalk, Buda lime	CreU & L	CL	Por	2,340	2,703	60	F	Buda lime	2,703
49	400	*y*		37	0.3	Serpentine	CreU	P	25	700	1,000	75	Intn	Travis Peak	3,290
50	*x*	*y*		34	0.4	Navarro sands	CreU	SH	10	506	730	20	F	Edwards lime	2,835
51	*x*	*y*		36	*y*	Serpentine	CreU	P	Por	1,230	1,336	*y*	Intn	Edwards lime	2,600
52	*y*	*y*		41	*y*	Wilcox sands	Eoc	S	22	5,512	5,578	66	*y*	Edwards lime	11,042
53	400	*y*		27	0.3	Serpentine	CreU	P	15–25	1,335	1,500	100	Intn	Edwards lime	2,600
54	150	*y*		30.4	0.8	Austin chalk	CreU	C	10	2,050	2,200	75	F	Edwards lime	2,600
						GAS ONLY									
55	*x*	*y*				Navarro-Taylor sands	CreU	SH	Por	900	*y*	*y*	F	Edwards lime	2,289
56	*x*	*y*		42–44	*y*	Buda, Edwards, Glen Rose	CreL	L	Por	3,205 3,255 5,650	*y*	*y*	A	Travis Peak	7,635
57	*y*	*y*				Navarro sand	CreU	S	Por	1,084	*y*	*y*	*y*	Taylor	3,005
58															

completed as an oil well in sand from 5498 to 5559 feet.

Also of interest in the future development of this field was the drilling of No. 3-A Washburn by the same company, about ¾ mile northwest of the discovery well. The No. 3-A well was drilled to a total depth of 11,042 ft., encountering the top of the typical Edwards limestone at 10,580 ft. and ending in a black limestone which has been correlated with the lower Cretaceous section of Mexico. Tests on the section below 5700 ft. showed gas and distillate, but the well was plugged back and completed as a flowing fresh-water well in the Carrizo sand at 3500 feet.

ACKNOWLEDGMENT

Appreciation and thanks are expressed to the various companies and individuals for their help and cooperation in furnishing many of the data on the various fields.

Oil and Gas Development in South Texas during 1941

By Michel T. Halbouty[*] Member, and James J. Halbouty,[†] Student Associate A.I.M.E.

Drilling activity in the South Texas area, which includes the South Corpus Christi and Laredo districts, showed a marked decline during 1941 from that of the preceding year. The rate of new discoveries, however, compared favorably with exploratory results of 1940 because of the many new productive sands opened in existing fields. South Texas completions for 1941 were about 12.3 per cent below the 1940 figure, compared with an increase of approximately 5.5 per cent in the total number of completions in the United States during 1941 over the 1940 total. During the year, 1452 wells were drilled in this area; of these, 1205 were drilled in or as extensions to the proven fields, and 247 were rank wildcats drilled in search of new producing pools. The comparable 1940 figures were: 1320 field or extension wells and 336 rank wildcats, a total of 1656 completions. This represents a decline in 1941 of approximately 8.7 per cent in proven-area wells, and of about 26.5 per cent in rank wildcats. It must be stressed that wells that were considered rank wildcats at the beginning of operations, but which opened production later classified as additions to existing fields, are not regarded as *rank* wildcats in this and previous annual reports on this same area. These wells are classified as *semiwildcats* (Table 2). There were 13 new oil or distillate fields and 4 new gas areas opened during the year, as listed in the next column.

Field	County	Discovery Well Produced
1. Agua Prieta	Duval	Oil
2. East Benavides	Duval	Oil
3. Coquat-Lopez*	Duval	Oil
4. Government Wells Yegua	Duval	Oil
5. Rios	Duval	Distillate and gas
6. Chaparosa	Jim Hogg	Gas
7. Neuhaus	Jim Hogg	Oil
8. Palacios*	Jim Hogg	Gas
9. Ramirez*	Jim Hogg	Gas
10. Sun-Jones*	Jim Hogg	Gas
11. South Campana	McMullen	Oil
12. Yturria	Starr	Oil
13. North Sun	Starr	Oil
14. Haldeman	Jim Wells	Oil
15. West Alfred (New)	Jim Wells	Oil
16. Petronilla	Nueces	Oil
17. Banquette	Nueces	Distillate and gas

* Not officially named.

This listing represents a decline of 32 per cent from the 25 new areas found during the previous year, and to a great extent can be attributed to the 26.5 per cent decline in wildcatting. The rate of new discoveries based on the 247 wildcats was 14.5 to 1, which compares somewhat unfavorably with the 13.4 to 1 ratio obtained in 1940 (Table 5). Dry wildcats totaled 230. The proof of the prolific character of the South Texas area as a source of petroleum reservoirs is to be found in the fact that of the 1205 field or extension (semiwildcat) wells completed during the past year 61 opened production from new sands or found crude in formerly distillate-producing sands. The 1940 total of 1320 such wells accounted for 50 horizons that provided either new production or crude in distillate sands, and in this respect the 1941 rate of discovery shows to greater advantage, the ratios for new sands being 19.7 to 1 for 1941 and 26.4 to 1 for 1940. The 1205 field or semiwildcat wells completed in 1941 resulted in 926 oil or dis-

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TABLE 1.—*Oil and Gas Production in South Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	During 1941	End of 1941		
										Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
1	Adami, *Webb*	1939	400	10	389,082	143,088	326	Frio	72	0	0	66	0
2	Agua Dulce,[1] *Nueces*	1928	2,760	11,600	1,362,497	514,935	100	Beaumont	208	87[5]	105	66	7
3	Agua Prieta, *Duval*	1941	20	0	4,058	4,058	425	Goliad	1	1	0	1	0
4	Albercas, *Webb*	1927	250	200	2,530,003	13,921	840	Goliad	100	0	0	15	8
5	Alfred,[2] *Jim Wells*	1938	500	0	367,739	166,769	193	Lissie	24	4	0	21	0
6	Alice, *Jim Wells*	1938	1,280	400	2,521,809	504,834	240	Lissie	76	2	7	53	1
7	East Alice (Tom Graham), *Jim Wells*	1938	750	360	1,195,933	390,239	209	Lissie	49	3	11	36	0
8	Alta Mesa, *Brooks*	1926	1,150	350	1,013,426	269,810	275	Sand Dunes	44	14	0	33	3
9	Alta Verde, *Brooks*[3]	1936	100	60	30,867	250	370	Goliad	6	0	0	0	0
10	Alworth,[4] *Jim Hogg*	1926	80	570	27,793	0	490	Cata.-Frio	16	0	0	0	0
11	Andrews, *Zapata*	1924	0	2,000	Gas		720	Frio	12	0	0	0	0
12	Angelita, *San Patricio*	1934	60	0	36,798	0	60	Beaumont	3	0	0	0	0
13	Aransas (gas), *San Patricio*	1931	0	760	Gas	Gas	60	Beaumont	19	0	0	0	2
14	Aransas Pass (McCampbell), *San Patricio and Aransas*	1936	3,200	450	10,685,115	2,021,159	10–30	Alluvium	362	4	26	227	5
15	Armagosa, *Jim Wells*	1931	0	400	Gas	Gas	300	Goliad	6	0	0	0	5
16	Arroyo Grande, *Starr*	1924	0	320	Gas		250	Jackson	8	0	0	0	0
17	Aviator, *Webb*	1922	955	320	6,080,009	97,889	860	Goliad	216	0	0	73	0
18	Baffins Bay, *Kleburg*	1940	20	0	5,610		Sea Level	Submerged	1	0	0	0	0
19	Baldwin (South Saxet), *Nueces*	1935	270	40	841,076	79,575	50	Beaumont	9	0	0	8	1
20	Bandera, *Jim Wells*	1938	0	80	1,987*y*	*y*	256	Lissie	2	0	2	0	0

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[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Includes North, East and South (Sullivan) Agua Dulce.

[2] Includes West Alfred.

[3] Temporarily abandoned.

[4] Depleted.

[5] One deepened well.

TABLE I.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941		Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells			Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift							Top Prod. Zone	Bottoms Prod. Wells				
1	0	66		20.8	Mirando	Eoc	S	Por	975	1,000	7	ML	Yegua	1,517
2	65	1	PM	Gas	Catahoula	Olig	S	Avg. = 30	1,998	2,400	10	AF	Yegua	13,728
				55	Frio	Olig	S		4,650	4,675	9			
				35.4–59	Frio	Olig	S		4,800	4,900	15			
				56	Frio	Olig	S		5,081	5,088	7			
				37.5–59.7	Frio	Olig	S		5,295	5,307	10			
				42.6–56	Frio	Olig	S		5,560	5,700	15			
				42.8–60	Frio	Olig	S		5,830	5,850	20			
				55–60	Frio	Olig	S		6,447	6,740	15			
				39.8–50.9	Frio	Olig	S		6,800	6,938	15			
				38.6–56	Frio	Olig	S		6,997	7,054	18			
				40.2	Frio	Olig	S		7,100	7,123	20			
				56	Frio	Olig	S		7,200	7,220	20			
3	1	0		46	Pettus	Eoc	S	Por	4,708	4,720	12	NF*y*	Yegua	5,025
4	0	15		20.4	McElroy	Eoc	S	Por	2,125	2,175	17	MF	Yegua	3,710
5	19	2		44.7	Frio	Olig	S	30–35	3,225	3,234	11	NFL	Jackson	6,535
				47.4	Frio	Olig	S	Por	4,194	4,206	12			
				48.5	Frio	Olig	S	Por	4,304	4,313	9			
				41.5	Vicksburg	Olig	S	30–35	4,660	4,695	15			
6	51	2	PM	42	Frio	Olig	S	28.7	3,480	3,600	16	ANL	Yegua	7,335
				38.9	Frio	Olig	S	Por	4,788	4,801	11			
				40	Frio	Olig	S	Por	5,030	5,161	12			
				44.8	Frio	Olig	S	Por	5,211	5,223	12			
				44–60	Vicksburg	Olig	S	Por	5,350	5,375	20			
				43.6	Vicksburg	Olig	S	Por	5,450	5,576	20			
7	36	0	PM	38	Frio	Olig	S	Por	3,480	3,496	15	ANL	Vicksburg	5,760
				54	Frio	Olig	S	Por	4,675	4,700	10			
				56	Frio	Olig	S	Por	5,125	5,175	12			
				42.6–56	Frio-Vicksburg	Olig	S	Por	5,300	5,400	18			
8	2	31		Gas	Oakville	Mio	S	Por	1,100	1,140	20	Ds	Jackson	8,022
				24.5	Catahoula	Olig	S	Por	2,434	2,600	12			
				24.5	Catahoula	Olig	S	Por	2,986	3,025	10			
				25.5	Catahoula	Olig	S	Por	3,475	3,585	20			
9	0	0		21.5	Caprock	Mio	S	Por	916	926	10	Ds	Jackson *y*	5,096
10	0	0		21	McElroy	Eoc	S	Por	1,020	1,030	6	ML	Yegua	2,199
11	0	0		Gas	McElroy	Eoc	S	Por	1,500	1,515	5	MF	Yegua	2,312
12	0	0		38	Frio	Olig	S	Por	5,370	5,382	10	NFL	Frio	7,131
				36	Frio	Olig	S	Por	6,225	6,235	10			
13	0	0		Gas′	Catahoula	Olig	S	Por	3,653	3,663	10	D	Frio	6,026
14	165	62		49.3	Marginulina	Olig	S	25–34	6,539	6,554	15	AF	Frio	9,492
				42.4	Frio	Olig	S		6,780	6,888	15			
				38.8	Frio	Olig	S		7,080	7,180	18			
				41.2	Frio	Olig	S		7,200	7,270	15			
				58	Frio	Olig	S		7,345	7,419	15			
				56	Frio	Olig	S		7,454	7,461	7			
15	0	0		Gas	Discorbis-Het.	Olig	S	Por	2,170	2,680	10	D	Yegua	6,315
16	0	0		Gas	Jackson	Eoc	S	Por	435	450	8	MF	Mt. Selman	4,015
				Gas	Cook Mt.	Eoc	S	Por	2,120	2,161	12			
				Gas	Mt. Selman	Eoc	S	Por	3,208	3,214	6			
17	0	73		21	Mirando	Eoc	S	Por	1,525	1,660	11	MfL	Cook Mt.	3,975
18	0	0		39.3	Frio	Olig	S	Por	7,394	7,450	10	AF	Frio	9,428
19	0	8		Gas	Oakville	Mio	S	Por	3,230	3,250	12	AF	Frio	6,610
				25.9	Catahoula	Olig	S	Por	3,874	3,880	6			
				23.3	Catahoula	Olig	S	Por	4,050	4,074	12			
20	0	0		Gas—56	Jackson	Olig	S	Por	6,408	6,416	8	AF	Yegua	8,302

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	During 1941	End of 1941		
										Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
21	Banquette, *Nueces*	1941	0	80	*y*	*y*	80	Beaumont	2	2	2	0	0
22	Barbacoas, *Starr*	1933	80	580	35,817	744	360	Goliad	14	0	0	1	0
23	Benavides (North Sweden), *Duval*	1937	3,900	600	10,620,374	1,562,764	350–450	Goliad	278	3	6	225	5
24	East Benavides, *Duval*	1941	20	0	8,761	8,761	350*y*	Goliad	1	1	0	1	0
25	Ben Bolt, *Jim Wells*	1939	2,400	280	1,619,535	782,181	196	Lissie	72	14	2	65	5
26	Bird Island, *Kleburg*	1938	40	80	38,040	14,217	Sea Level	Submerged	3	0	2	1	0
27	Blanchard (Muralla), *Duval*	1939	60	40	38,627	12,797	490	Goliad	4	1	1	2	0
28	Blas Uribe, *Zapata*	1934	0	80	Gas	Gas	500	Jackson	3	0	0	0	1
29	Blucher, *Jim Wells*	1939	0	40	3,461*y*	*y*	140	Lissie	1	0	0	0	0
30	Boyle, *Starr*	1940	200	20	96,183	71,484	275	Goliad	11	3	1	10	0
31	Bridwell, *Duval*	1940	200	20	74,409	62,015	425	Goliad	11	6	0	10	0
32	Calliham (includes South Calliham), *McMullen*	1918	500	730	935,957	55,100	235	Jackson	142	1	0	60	1
33	Camada, *Jim Wells*	1939	40	0	4,328	513	287	Lissie	2	0	0	1	0
34	Campana, *McMullen*	1938	10	0	512*y*	201	494	Lagarto	1	0	0	1	0
35	South Campana, *McMullen*	1941	120	20	17,345	17,345	525	Lagarto	7	7	0	6	0
36	Captain Lucey (West Bentonville), *Jim Wells*	1932	120	520	527,738	44,214	140	Beaumont	23	1	4	6	5
37	Carolina-Texas, *Webb*	1921	110	1,460	264,884	132	800	Goliad	66	0	3	0	4
38	Casa Blanca (includes West Casa Blanca), *Duval*	1938	500	120	504,404	159,853	460	Catahoula	70	23	0	55	9
39	North Casa Blanca, *Duval*	1939	100	0	93,811	34,022	460	Catahoula	9	0	0	9	0
40	Cedro Hill, *Duval*	1938	760	40	517,681	273,991	542	Catahoula	81	8	0	76	4
41	Chaparosa, *Jim Hogg*	1941	0	40	Gas	Gas	700	Catahoula	2	2	0	0	0
42	Chapman Ranch, *Nueces*	1937	100	80	57,058	13,276	50	Beaumont	5	3	1	2	0
43	Charamousca (includes South Charamousca), *Duval*	1935	410	0	646,051	186,221	410	Catahoula	41	19[5]	0	34	0

TABLE I.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941		Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells			Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift							Top Prod. Zone	Bottoms Prod. Wells				
21	0	0		Gas—58.6	Frio	Olig	S	Por	6,705	6,714	9	A	Frio	7,538
				Gas—56	Frio	Olig	S	Por	6,978	6,983	5			
22	1	0		Gas	Catahoula	Olig	S	Por	200	715	10	AF	Yegua	6,567
				Gas—24.9	Frio	Olig	S	Por	2,450	2,950	15			
				58	Cockfield	Eoc	S	Por	5,376	5,398	22			
23	138	87		41.8	Cole	Eoc	S	Avg. = 27	3,840	3,975	22	[6] AF	Yegua	6,510
				42.9	Chernosky	Eoc	S		4,357	4,552	15			
				47.2	Upper Govt. Wells	Eoc	S		4,730	4,755	20			
				43.3	Lower Govt. Wells	Eoc	S		4,755	4,830	25			
				39.6–60	Pettus	Eoc	S		5,310	5,382	22			
				45	Yegua	Eoc	S		5,486	5,518	17			
				56	Yegua	Eoc	S		5,584	5,594	10			
				65	Yegua	Eoc	S		5,721	5,749	20			
24	1	0		43	Govt. Wells	Eoc	S	Por	4,915	4,940	20	AF	Yegua	6,510
25	65	0		30	Frio	Olig	S	Por	4,863	4,875	12	ANL	Jackson	6,140
				42.5	Frio	Olig	S	Por	4,900	4,920	15			
				42	Frio	Olig	S	32.7	5,174	5,317	15			
				42.5	Vicksburg	Olig	S	Por	5,370	5,671	15			
26	1	0		44	Frio	Olig	S	Por	7,200	7,310	80	AF	Frio	9,636
27	2	0		43–46.1	Pettus	Eoc	S	Por	4,683	4,822	8	MF	Yegua	5,807
28	0	0		Gas	Yegua	Eoc	S	Por	1,825	1,840	15	ML	Cook Mt.	3,000
29	0	0		54	Vicksburg	Olig	S	Por	7,500	7,560	20	A	Vicksburg	8,004
30	9	1		Gas-dist.	Frio	Olig	S	Por	2,850	2,855	5	AF	Jackson	4,520
				47.7	Frio	Olig	S	Por	3,149	3,186	15			
				44	Frio	Olig	S	Por	3,475	3,503	12			
31	10	0		43.5	Pettus	Eoc	S	Por	4,292	4,335	10	MF	Yegua	4,657
32	0	60		20	Mirando[8]	Eoc	S	Por	848	876	15	MF	Carrizo	5,301
				20.6	Gov. Wells—Pettus[8]	Eoc	S	Por	1,030	1,060	10			
				Gas	Loma Novia	Eoc	S	Por	1,221	1,250	10			
33	1	0		44.3	Chernosky	Eoc	S	Por	5,627	5,637	10	NL	Yegua	7,041
34	0	1		24	Govt. Wells	Eoc	S	Por	2,492	2,517	20	MF	Pettus	3,102
35	6	0		Gas	Govt. Wells	Eoc	S	Por	2,554	2,568	10	MF	Yegua	3,590
				22.8	Pettus	Eoc	S	Por	3,012	3,023				
36	5	1		Gas	Frio	Olig	S	Por	3,893	4,000	6	AF	Jackson	6,500
				36.4	Frio	Olig	S	Por	5,350	5,370	20			
				41.4	Vicksburg	Olig	S	Por	5,679	5,685	7			
37	0	0		Gas	Cole	Eoc	S	Por	1,270	1,305	10	DF	Queen City	5,527
				Gas	McElroy	Eoc	S	Por	1,800	2,200	10			
				34	Cockfield	Eoc	S	Por	2,597	2,615	10			
				27.6	Yegua	Eoc	S	Por	2,947	3,198	18			
				42–60	Queen City	Eoc	S	Por	4,996	5,056	60			
38	0	55		20	Cole[9]	Eoc	S	Por	994	1,045	10	ML	Yegua	2,212
				20	Cole	Eoc	S	Por	1,180	1,190	10			
39	0	9		20.8	Cole	Eoc	S	Por	1,030	1,059	9	ML	Jackson	1,788
40	16	60		19.2	Cole	Eoc	S	Por	1,436	1,480	10	MFL	Yegua	2,646
41	0	0		Gas	Upper Govt. Wells	Eoc	S	Por	2,781	2,792	10	ML	Pettus	3,465
				Gas	Lower Govt. Wells	Eoc	S	Por	2,855	2,868	10			
42	0	2		27.9	Catahoula	Olig	S	Por	4,244	4,279	10	NL	Frio	7,750
				40.8	Catahoula	Olig	S	Por	5,046	5,058	12			
				41.8	Frio	Olig	S	Por	6,464	6,484	20			
43	4[7]	30		20	Cole	Eoc	S	Por	1,094	1,101	7	MF	Cook Mt.	3,892
				19.8	McElroy	Eoc	S	Por	1,525	1,581	10			

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[6] Also lensed sands are found at 3495–3510 ft. in two wells (40.4 gravity oil) and at 5067–5123 ft. (44.2 gravity oil).

[7] In South Charamousca.

[8] In Calliham.

[9] In West Casa Blanca.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
										During 1941	End of 1941		
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
44	Charco Redondo, *Zapata*	1913	570	60	195,624	5,566	450	Jackson	340	12	0	21	0
45	Chiltipin, *Duval*	1939	60	20	29,024	14,915	393	Goliad	6	2	1	3	0
46	Clara Driscoll,[9a] *Nueces*	1935	2,550	400	4,292,829	1,205,133	50-80	Beaumont	176	39	7	132	12
47	Clark-Muil, *Jim Wells*	1939	80	100	44,119	2,949	191	Lissie	8	0	2	0	0
48	Clopton-Green, *Starr*	1937	0	10	Gas		275*y*	Goliad	1	0	0	0	0
	Cole Group, *Duval, Webb*	1924					700-800	Goliad					
49	Shallow (includes East Cole)	1924	120	7,000	7,810	3,976	780	Goliad	112	5	0	2	62
50	O'Hern	1927	2,300	2,200	10,749,772	952,441	780	Goliad	274	0	0	190	17
51	Bruni (includes East Bruni)	1934	880	160	2,822,667	54,801	780	Goliad	62	0	0	26	1
52	West Cole, *Webb*	1927	500	1,000	4,637,729	207,633	790	Goliad	126	0	0	68	6
53	Colmena, *Duval*	1934	240	400	474,674	79,217	600	Catahoula	36	0	0	25	4
54	Colorado, *Jim Hogg*	1936	1,860	40	1,926,143	941,960	550	Catahoula	192	75	0	186	1
55	Comitas (Haynes), *Zapata*	1934	750	40	1,698,234	169,106	415	Frio	196	0	0	148	0
56	Conoco Driscoll, *Duval*	1924	1,340	980	3,839,999	894,404	600	Goliad	94	14	1	67	3
57	Coquat-Lopez,[10] *Duval*	1941	10	0	*y*	*y*	680	Goliad	1	1	0	1	0
58	Corpus Christi (Saxet Heights), *Nueces*	1935	1,500	200	6,838,641	94,582	10-60	Beaumont	252	1[5]	4	19	0
59	Crowther,[4] *McMullen*	1915	80	0	25,000	0	190	Jackson	23	0	0	0	0
60	Cuellar, *Zapata*	1927	340	220	2,614,524	20,823	550	Frio	86	0	0	24	3
61	Eagle Hill, *Duval*	1933	550	200	1,478,081	262,319	550	Catahoula	61	0	0	55	3
62	Edinburg, *Hidalgo*	1935	20	0	500	0	100	Beaumont	1	0	0	0	0
63	El Mesquite, *Duval*	1935	10	0	976	0	670	Goliad	1	0	0	0	0
64	El Tanque (South Ricaby), *Starr*	1937	280	30	415,034	54,823	285	Goliad	22	0	0	16	0
65	Escobas-Jennings, *Zapata*	1914	3,700	2,000	9,875,577	691,844	480-520	Jackson	538	3	0	348	5[15]
66	Ezzell, *McMullen, Live Oak*	1937	1,450	100	2,464,297	306,297	140-200	Catahoula	151	2	0	128	0
67	Fitzsimmons, *Duval*	1938	790	0	2,323,711	561,084	460	Goliad	79	0	0	78	1
68	East Fitzsimmons, *Duval*	1940	10	0	600*y*	*y*	420	Goliad	1	0	0	0	0
69	Flour Bluff, *Nueces*	1936	2,280	320	6,985,939	1,103,835	0-50	Alluvium	116	0	7	99	4
70	East Flour Bluff, *Nueces*	1940	800	40	251,474	217,724	Sea Level	Submerged	21	11	0	20	0
71	Gallagher, *Jim Wells*	1940	60	0	59,472	33,309	75	Lissie	3	0	0	3	0

[9a] Includes South Clara Driscoll and Gandy (sands at 5440 and 5850 ft.).
[10] Not officially named.
[15] In Jennings.

TABLE 1.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941		Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells			Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift							Top Prod. Zone	Bottoms Prod. Wells				
44	0	21		17	Jackson	Eoc	S	Por	150	200	8	ML	Mt. Selman	3,511
				Gas	Jackson	Eoc	S	Por	989	995	5			
45	2	1		49.6	Pettus	Eoc	S	Por	4,760	4,795	10	NF	Yegua	5,410
46	89	43		Gas	Catahoula	Olig	S	Por	3,250	3,300	15	AF	Vicksburg	8,194
				23.5	Heterostegina	Olig	S	Por	3,787	3,980	12			
				31.5	Frio	Olig	S	Por	4,642	4,748	10			
				37.3	Frio	Olig	S	Por	4,986	5,133	15			
				34.2–38.6	Frio	Olig	S	Por	5,255	5,477	15			
				38.6–58	Frio	Olig	S	Por	5,502	5,890	15			
				38.5	Frio	Olig	S	Por	6,487	6,660	10			
47	0	0		60	Frio	Olig	S	Por	4,795	4,835	20	N	Vicksburg	5,850
				40.2	Frio	Olig	S	Por	5,326	5,330	4			
				58	Vicksburg	Olig	S	Por	5,557	5,572	12			
48	0	0		Gas	Cole	Eoc	S	Por	1,604	1,614	10	ML	Cook Mt.	4,620
					Frio-Queen City				500	5,675		AF	Wilcox	10,295
49	0	2[11]		Gas	Frio	Olig	S	Por	500	515	10	AfL	Reklaw	6,394
				Gas—20	Cole	Eoc	S	Por	1,650	1,820	10			
50	0	190		29.4	McElroy	Eoc	S	Por	2,300	2,450	10	AFL	Reklaw	6,394
				Gas	O'Hern-Cockfield	Eoc	S	Por	2,750	2,945	15			
51	6[12]	20		39.9	Yegua	Eoc	S	Por	3,250	3,280	10	AF	Wilcox	10,295
				38.5–42.4	Yegua	Eoc	S	Por	3,400	3,450	14			
				44	Cook Mt.	Eoc	S	Por	3,938	3,973	15			
				46	Queen City	Eoc	S	Por	5,620	5,675	15			
52	0	68		21.5	McElroy	Eoc	S	Por	2,300	2,350	11	ML	Queen City	5,525
				Gas	Cockfield	Eoc	S	Por	2,900	2,925	10			
53	1	24		18.9	Cole	Eoc	S	Por	1,486	1,553	10	ML	Yegua	3,396
54	164	22		47.2	Cockfield	Eoc	S	Por	3,000	3,050	10	ML	Yegua	3,442
55	0	148		20.6	McElroy	Eoc	S	Por	800	1,000	10	ML	Cook Mt.	3,502
56	58	9		22.5	Frio	Eoc	S	Por	2,448	2,535	20	[13] NL	Cook Mt.	4,695
				23.4	Cole	Eoc	S	Por	2,884	2,904	10			
				36.4	Govt. Wells	Eoc	S	Por	3,250	3,561	15			
57	0	1		20.6	Cole	Eoc	S	Por	1,693	1,705	12	ML	Cole	1,705
58	16	3		25	Catahoula	Olig	S	Por	3,974	4,100	8	A	Frio	7,531
				36.5	Heterostegina.	Olig	S	Por	5,157	5,167	10			
59	0	0		18	Diboll	Eoc	S	Por	500	520	10	ML	Cook Mt.	2,000
60	0	24		Gas	McElroy	Eoc	S	Por	1,100	1,116	16	ML	Mt. Selman	4,532
				20.9	McElroy	Eoc	S	Por	1,325	1,350	10			
61	0	55		19	Cole	Eoc	S	Por	1,450	1,540	10	MF	Yegua	2,752
				23	Govt. Wells	Eoc	S	Por	2,120	2,150	11			
62	0	0		*y*	Frio	Olig	S	Por	6,685	6,770	20	D	Frio	7,508
63	0	0		43	Cockfield	Eoc	S	Por	2,850	2,862	12	ML	Yegua	3,502
64	2	14		Gas	Catahoula	Olig	S	Por	425	429	4	NL	Jackson	2,700
				31	Frio	Olig	S	Por	1,702	1,775	14			
				30	Frio	Olig	S	Por	1,866	1,879	6			
65	0	348		20.9	Jackson	Eoc	S	Por	900	1,050	10	AFL	Mt. Selman	4,645
				20.9	Jackson	Eoc	S	Por	1,137	1,350	15			
				20.9	Jackson *y*-Yegua	Eoc	S	Por	1,450	1,900	10			
66	0	128		20	Loma Novia	Eoc	S	Por	1,490	1,550	11	ML	Cook Mt.	3,108
67	65	13		46	McElroy	Eoc	S	Por	3,592	3,623	15	MF	Yegua	5,285
				47	Pettus	Eoc	S	Por	4,260	4,303	25			
68	0	0		43.7	Yegua	Eoc	S	Por	4,900	4,916	10	MF	Yegua	5,087
69	84	15		41.5–45.8	Marginulina	Olig	S	Por	6,590	6,696	20	AF	Frio	7,504
70	20	0		41.6	Marginulina	Olig	S	Por	6,753	6,800	20	AF	Frio	8,694
71	3	0		39.4	Frio	Olig	S	Por	5,189	5,226	18	NFL	Jackson	6,260
				39.4	Vicksburg	Olig	S	Por	5,744	5,761	15			

[11] In East Cole.
[12] In Bruni.
[13] Also Oakville gas sand at 500 ft.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formaton	Completed to End of 1941	During 1941	End of 1941		
										Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[d]
72	Glen-Webb, *Zapata*	1940	690	60	509,972	400,696	860	Cata.-Frio	75	27	2	68	0
73	Government Wells,[14] *Duval*	1928	7,500	600	48,227,149	3,052,350	500–600	Catahoula	833	3	0	643	6
74	Guerra (Cuevitas), *Starr*	1933	400	400	1,206,302	93,630	475	Goliad	21	0	0	13	5
75	Haldeman, *Jim Wells*	1941	20	0	7,136	7,136	175	Lissie	1	1	0	2	0
76	Hayden, *Starr*	1937	0	40	Gas		180	Catahoula	2	0	0	0	0
77	Henne-Winch-Farris, *Jim Hogg*	1924	720	440	3,214,174	1,917	640	Goliad-Cata.	181	0	0	1	0
78	Henshaw, *Jim Wells*	1940	30	30	21,925	16,743	120	Lissie	2	0	1	1	0
79	Hoffman, *Duval*	1933	3,360	500	7,392,878	2,040,454	700	Goliad-Cata.	377	12	1	334	15
80	Holbein, *Jim Hogg*	1940	100	0	38,483	35,892	840	Goliad	10	9	0	10	0
81	Holland-Hebbronville (Gutierrez), *Jim Hogg*	1939	10	10	2,199*y*	*y*	685	Goliad	2	0	0	0	1
82	Jacob (includes North Jacob), *McMullen*	1926	1,230	80	1,602,337	115,257	190	Jackson	129	2	0	70	0
83	Kelsey, *Jim Hogg, Brooks, Starr*	1938	2,300	160	1,728,321	776,860	260	Sand Dunes	119	34	3	111	1
84	Killam, *Webb*	1937	650	150	967,052	157,457	870	Goliad	128	36	0	89	0
85	North Killam (includes Houser), *Webb*	1938	80	20	48,321	11,347	914	Goliad	7	0	0	6	0
86	Kingsville, *Kleburg*	1920	240	675	746,934	15,182	50	Beaumont	20	0	0	5	2
87	Kohler (includes North (deep) Kohler), *Duval*	1926	360	5,000	663,164	22,670	800	Goliad	92	1	1	11	17
88	Kreis, *Duval*	1940	160	0	21,002	20,702	560	Goliad	8	7	0	7	0
89	Labbe, *Duval*	1934	200	500	375,691	74,417	675	Goliad	31	2	0	14	8
90	La Blanca, *Hidalgo*	1936	0	3,250	533,540*y*	*y*	65	Beaumont	10	0	7	0	0
91	La Gloria, *Jim Wells, Brooks*	1939	40	1,360	37,324	15,014	140	Lissie	35	14*y*	34	1	0
92	La Reforma, *Starr*	1938	40	120	12,902	2,567	270	Goliad	4	1	3	1	0

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[14] Includes Govt. Wells Yegua Area.

TABLE 1.—(*Continued*)

	Crude-oil-production Methods, End of 1941			Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells								Depth, Avg. Ft.					
Line Number	Flowing	Artificial Lift	Repressuring Operation[d]	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft
72	8	60		22.1	Mirando	Eoc	S	Por	2,160	2,185	12	NL	Yegua	2,861
73	0	643		Gas	Cole	Eoc	S	Por	1,550	1,575	17	NF	Mt. Selman	5,858
				21.6–23	Govt. Wells	Eoc	S	Por	2,200	2,380	19			
				26	Mirando	Eoc	S	Por	2,400	2,450	11			
				26–36.2	Yegua	Eoc	S	Por	2,936	2,985	4			
74	8	5		34.5	Cole	Eoc	S	Por	1,745	1,785	10	MF	Yegua	3,600
				32	McElroy	Eoc	S	Por	2,047	2,055	8			
				34.5	McElroy	Eoc	S	Por	2,209	2,232	23			
75	2	0		40.3	Frio	Olig	S	Por	5,019	5,040	16	NF	Jackson	6,498
76	0	0		Gas	Frio	Olig	S	Por	1,305	1,318	13	ML	Jackson	2,644
				Gas	Jackson	Eoc	S	Por	2,619	2,644	25			
77	0	1		20.2	Mirando	Eoc	S	Por	1,944	2,100	16	MF	Yegua	3,546
78	1	0		53	Frio	Olig	S	Por	3,780	3,792	12	NF	Vicksburg	5,885
				31.1	Frio-Vicksburg	Olig	S	Por	5,133	5,144	10			
79	5	329		26–28	Argo (locally)	Eoc	S	Por	2,550	2,595	20	[16] NL	Yegua	3,800
				20–21	Govt. Wells	Eoc	S	Por	2,650	2,750	15			
				23–25	Lomia Novia	Eoc	S	Por	2,775	2,900	25	Af		
				26	Cockfield	Eoc	S	Por	3,142	3,152	10			
80	0	10		24.5	Pettus	Eoc	S	Por	2,793	2,828	15	NL	Yegua	3,150
81	0	0		32.6	Loma Novia	Eoc	S	Por	3,217	3,223	6	NL	Yegua	3,731
				55	Pettus	Eoc	S	Por	3,618	3,656	15			
82	0	70		Gas	Mirando	Eoc	S	Por	780	790	8	ML	Mt. Selman	3,171
				21.5	Pettus	Eoc	S	Por	920	975	7			
				20.5	Yegua	Eoc	S	Por	1,050	1,070	8			
83	111	0		44.7	Frio	Olig	S	Por	4,671	4,754	15	A	Yegua	7,507
				45	Frio	Olig	S	Por	4,924	4,945	15			
				42	Govt. Wells	Eoc	S	Por	6,099	6,107	8			
				55	Jackson	Eoc	S	Por	6,420	6,440	15			
84	0	89		21–22	Mirando	Eoc	S	Por	1,920	2,035	12	ML	Yegua	3,011
				Gas—45	Cockfield	Eoc	S	Por	2,475	2,500	15			
85	0	6		22	Mirando	Eoc	S	Por	2,046	2,096	7	ML	Yegua	3,060
				Gas—45	Cockfield	Eoc	S	Por	2,492	2,524	23			
86	0	5		21.5	Miocene	Mio	S	Por	1,400	2,900	20	D	Frio	6,922
				22	Catahoula	Olig	S	Por	3,217	3,238	20			
87	3	8		21.5	Cole	Eoc	S	Por	1,748	1,850	12	ML	Carrizo	7,723
				21.5	Govt. Wells	Eoc	S	Por	2,438	2,500	12			
				22.5	Mirando	Eoc	S	Por	2,613	2,800	29			
88	5	2		29.2	Mirando	Eoc	S	Por	3,204	3,258	9	ML	Cockfield	3,433
89	2	12		Gas	Cole	Eoc	S	Por	1,872	1,902	10	ML	Yegua	4,054
				Gas	Chernosky	Eoc	S	Por	2,453	2,460	7			
				25.4	Loma Novia	Eoc	S	Por	2,800	2,900	19			
90	0	0	PM	62	Frio	Olig	S	Por	6,650	6,683	20	D	Vicksburg	8,893
				52	Frio	Olig	S	Por	7,450	7,480	25			
				48	Frio	Olig	S	Por	7,840	7,875	20			
				56	Frio	Olig	S	Por	8,035	8,075	25			
91	0	1	PM	55	Frio	Olig	S	Por	5,912	5,990	15	A	Jackson	8,043
				55	Frio	Olig	S	Por	6,037	6,132	15			
				55	Frio	Olig	S	Por	6,180	6,205	18			
				56	Frio	Olig	S	Por	6,533	6,598	15			
				39.5	Frio	Olig	S	Por	6,670	6,700	15			
				55	Frio	Olig	S	Por	6,790	6,820	20			
				60	Frio	Olig	S	Por	6,998	7,011	12			
				56.6	Frio	Olig	S	Por	7,066	7,088	20			
				55	Vicksburg[17]	Olig	S	Por	7,138	7,168	20			
				25	Vicksburg[17]	Olig	S	Por	7,210	7,232	20			
92	1	0		51.6	Frio	Olig	S	Por	5,917	5,969	52	AF	Jackson *y*	7,010
				42	Vicksburg	Olig	S	Por	6,140	6,168	28			

[16] Also gas sand in Frio at 1760–80 ft.
[17] May be same sand.

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	During 1941	End of 1941		
										Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
93	South La Reforma, *Starr*	1939	0	40	Distillate	y	308	Goliad	1	0	1	0	0
94	Las Animas, *Jim Hogg*	1937	50	80	40,298	3,686	835	Goliad	10	2	0	1	1
95	La Sal Vieja, *Willacy*	1936	40	0	17,954	0	60	Alluvium	1	0	0	0	0
96	Laurel, *Webb*	1932	220	320	691,054	4,078	760–800	Goliad	33	0	0	4	2
97	Leaseholders,[18] *Webb*	1922	10	20	25,000	0	540	Catahoula	3	0	0	0	0
98	Loma Alta, *McMullen*	1935	80	0	146,248	15,734	700	Catahoula	4	0	0	3	0
99	Loma Novia, *Duval*	1934	7,410	270	25,146,143	2,191,586	630–720	Gol.-Oak.-Cata.	758	0	0	585	4
100	Loma Valdez, *Webb*	1938	0	10	Gas		808	Goliad	1	0	0	0	0
101	Loma Vista, *Duval*	1936	10	10	19,813	60	685	Oak.-Cata.	2	0	0	0	0
102	London, *Nueces*	1937	80	40	83,764	14,027	50	Beaumont	4	0	0	2	0
103	Longhorn, *Duval*	1938	960	40	1,556,267	442,926	374	Goliad	48	0	1	42	0
104	Lopena, *Zapata*	1934	0	1,100	Gas	Gas	300	Yegua	22	12[19]	0	0	22
105	Lopez, *Webb, Duval*	1935	3,450	240	11,504,741	1,444,326	600–680	Catahoula	369	0	0	315	2
106	Los Olmos, *Starr*	1925	240	310	635,397	20,341	225	Frio	110	2	0	74	0
107	Los Picachos, *Duval*	1938	20	0	576	0	471	Catahoula	1	0	0	0	0
108	Luby (includes Luby Deep), *Nueces*	1937	3,000	60	6,826,121	1,387,251	40	Beaumont	152	4[5]	1	148	2
109	East Luby, *Nueces*	1940	0	40	Included in Luby		35	Beaumont	1	0	1	0	0
110	North Luby, *Nueces*	1939	80	0	65,558	29,492	54	Beaumont	4	1	0	3	0
111	Lundell, *Duval*	1937	940	160	1,086,088	437,740	570	Catahoula	104	14	0	94	8
112	Magnolia City, *Jim Wells*	1939	120	80	145,313	35,963	162	Lissie	9	0	4	3	0
113	Manila, *Jim Hogg*	1940	230	30	158,513	115,345	615	Catahoula	26	12	0	23	3
114	Martinez, *Zapata*	1929	0	850	Gas	Gas	700	Frio-Jack.	27	0	0	0	22
115	Mathis, *San Patricio*	1924	0	100	Gas		90	Goliad	6	0	0	0	0
116	East Mathis, *San Patricio*	1939	60	40	14,995	7,521	134	Beaumont	3	0	0	1	1
117	McAllen (Pharr), *Hidalgo*	1938	0	360	15,826	4,995	127	Beaumont	3	1	3	0	0
118	McBride, *Webb*	1940	0	40	Gas		800y	Goliad	1	0	0	0	0
119	Mercedes (Capsillo), *Hidalgo*	1935	0	560	169,525	6,998	60	Beaumont	7	0	7	0	0
120	Mestinas, *Hidalgo*	1935		Included in San Salvador			50	Beaumont			See San Salvador		
121	Midway, *San Patricio*	1937	1,060	80	1,507,334	627,166	40	Beaumont	57	35	1	50	0
122	Minnie Bock, *Nueces*	1939	780	60	1,077,164	594,650	60	Beaumont	69	30	3	60	0
123	Mirando City, *Webb*	1921	1,430	500	9,206,634	101,048	850	Cata-Frio	295	0	0	66	1
124	Mirando Valley, *Zapata*	1921	1,000	320	1,433,212	148,652	700	Goliad	146	0	0	72	3
125	Moca, *Webb*	1932	100	20	1,137,770	82,762	500	Frio	12	0	0	11	0
126	Munson, *McMullen*	1938	150	20	159,504	33,288	335	Frio	17	0	0	14	0
127	Neuhaus, *Jim Hogg*	1941	10	0	60	60	690	Catahoula	1	1	0	1	0
128	Nichols, *Hidalgo*	1940	200	0	62,893	60,954	150	Goliad	12	11	0	10	0

[18] Field abandoned.

[19] Includes 5 deepened wells.

TABLE 1.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941: Number of Wells: Flowing	Crude-oil-production Methods, End of 1941: Number of Wells: Artificial Lift	Repressuring Operation[d]	Character of Oil: Gravity A.P.I. at 60°F., Weighted Average	Producing Formation: Name	Producing Formation: Age[e]	Producing Formation: Character[f]	Producing Formation: Porosity[g]	Producing Formation: Depth, Avg. Ft.: Top Prod. Zone	Producing Formation: Depth, Avg. Ft.: Bottoms Prod. Wells	Producing Formation: Net Thickness, Avg. Ft.	Producing Formation: Structure[h]	Deepest Zone Tested to End of 1941: Name	Deepest Zone Tested to End of 1941: Depth of Hole, Ft.
93	0	0		51.5	Frio	Olig	S	Por	5,798	5,832	34	AF	Vicksburg	6,566
94	0	1		18.5	Cole	Eoc	S	Por	1,782	1,828	22	A	Cook Mt.	4,014
95	0	0		48	Frio	Olig	S	Por	7,630	7,646	16	D	Frio	10,286
96	0	4		Gas	Frio	Olig	S	Por	360	366	6	MF	Cook Mt.	3,165
				Gas	Mirando	Eoc	S	Por	1,770	1,777	6			
				49	Cockfield	Eoc	S	Por	2,211	2,275	7			
97	0	0		22	Cole[20]	Eoc	S	Por	1,000	1,055	6	ML	Yegua	3,034
98	0	3		21–21.5	Chernosky	Eoc	S	Por	2,195	2,250	12	MF	Cockfield	2,766
99	0	585	RP	23.9–26	Loma Novia	Eoc	S	Por	2,550	2,705	25	ML	Cook Mt.	4,200
				22	Mirando	Eoc	S	Por	2,846	2,900	15			
100	0	0		Gas	Cole	Eoc	S	Por	1,790	1,812	19	NL	Yegua	3,528
101	0	0		25.7	Loma Novia	Eoc	S	Por	2,914	2,922	7	ML	Cook Mt.	4,732
102	0	2		24.4	Catahoula	Olig	S	Por	4,698	4,730	8	NF	Frio	7,424
				51	Catahoula	Olig	S	Por	4,752	4,906	10			
103	34	8		41.7	Cole	Eoc	S	Por	4,009	4,100	10	AF	Yegua	6,011
				45.7	Govt. Wells	Eoc	S	Por	4,885	4,914	10			
104	0	0		Gas	Queen City	Eoc	S	Por	2,137	2,180	20	A	Mt. Selman	3,502
				Gas	Queen City	Eoc	S	Por	2,416	2,462	20			
				Gas	Queen City	Eoc	S	Por	2,500	2,535	20			
105	76	239		20.7	Mirando	Eoc	S	Por	2,126	2,250	18	ML	Yegua	3,437
106	0	74		20	Frio	Olig	S	Por	250	700	17	MF	Yegua	2,612
107	0	0		24	Govt. Wells	Eoc	S	22–26	2,166	2,196	15	MF	Govt. Wells	2,196
108	141	7		45.7	Catahoula	Olig	S	Por	4,306	4,354	15	AF	Frio	7,595
				45.7	Heterostegina	Olig	S	Por	5,009	5,087	20			
				45.7	Heterostegina	Olig	S	Por	5,155	5,175	10			
				37.2	Frio	Olig	S	Por	7,308	7,313	5			
109	0	0		56	Oakville	Mio	S	Por	4,023	4,038	15	AF	Frio	7,628
110	1	2		45.7	Catahoula	Olig	S	Por	4,347	4,370	14	AF	Frio	7,440
				45.7	Heterostegina	Olig	S	Por	5,073	5,085	12			
111	35	59		19.3	Cole	Eoc	S	Por	1,500	1,530	10	MF	Yegua	2,698
112	2	1		42.7	Frio	Olig	S	27.7	5,436	5,485	10	A	Jackson	6,592
				Gas	Frio	Olig	S	Por	5,561	5,569	8			
				40.8	Frio	Olig	S	Por	5,692	5,726	10			
113	4	19		24.9	Pettus	Eoc	S	Por	2,541	2,650	10	NL	Yegua	3,006
114	0	0		Gas	McElroy	Eoc	S	Por	1,860	1,927	6	ML	Cook Mt.	3,514
115	0	0		Gas	Catahoula	Olig	S	Por	2,375	2,414	10	MF	Jackson	5,526
116	1	0		54	Frio	Olig	S	Por	4,417	4,422	5	ANF	Jackson	6,348
				35.5	Frio	Olig	S	Por	5,258	5,270	12			
				41	Vicksburg	Olig	S	Por	5,600	5,627	10			
117	0	0		61.5	Frio	Olig	S	Por	5,970	5,994	24	D	Vicksburg	8,575
				58–60	Frio	Olig	S	Por	6,500	6,955	20			
				53	Frio	Olig	S	Por	7,415	7,550	25			
118	0	0		Gas	Mirando	Eoc	S	Por	2,525	2,539	14	ML	Yegua	3,470
119	0	0		49.2–61	Frio	Olig	S	Por	7,430	7,524	16	DF	Vicksburg *y*	9,618
				50–60	Frio-Vicksburg	Olig	S	Por	7,500	9,500	15			
120				52–60	Frio	Olig	S	Por	6,658	6,748	90	D	Frio	8,123
121	43	7		28.4	Frio	Olig	S	Por	5,285	5,370	15	Af	Frio	7,003
				46.5	Frio	Olig	S	Por	6,048	6,051	3			
				42.3	Frio	Olig	S	Por	6,255	6,280	25			
122	31	29		24.5	Catahoula	Olig	S	Por	3,698	3,712	14	AF	Frio	7,510
				23.5	Catahoula	Olig	S	Por	3,787	3,900	15			
				55	Frio	Olig	S	Por	5,510	5,518	8			
123	0	66		20.6	McElroy	Eoc	S	Por	1,530	1,540	10	ML	Mt. Selman	5,000
				45	Cockfield	Eoc	S	Por	1,925	1,935	10			
124	2	70		20.9	McElroy	Eoc	S	Por	1,400	1,450	7	ML	Cook Mt.	3,660
				20.9	Mirando	Eoc	S	Por	1,790	2,000	10			
125	0	11		21	Mirando	Eoc	S	Por	900	950	10	MF	Yegua	2,178
126	0	14		22.5–20.7	Mirando	Eoc	S	Por	1,200	1,215	12	ML	Pettus	1,501
127	1	0		45*y*	Pettus	Eoc	S	Por	3,462	3,471	9	MF *y*	Pettus	3,471
128	10	0		Gas	Frio	Olig	S	30	3,132	3,138	6	AF	Jackson	4,528
				26	Frio	Olig	S		3,498	3,515	10			
				34.7	Frio	Olig	S		3,670	3,678	8			
				37.6	Frio	Olig	S		3,869	3,912	8			

[20] Also gas produced from Frio at 270 ft.

TABLE I.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
										During 1941	End of 1941		
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
129	Odem, *San Patricio*....	1939	260	60	42,149	38,036	90	Beaumont	16	14	2	12	1
130	Oilton, *Webb*..........	1937	700	150	1,610,611	153,829	850–900	Goliad	141	0	0	82	0
131	Orange Grove, *Jim Wells*..............	1940	810	90	574,815	383,179	180	Lissie	32	12	0	29	3
132	Palacios,[10] *Jim Hogg*...	1941	0	20	Gas	Gas	600	Catahoula	1	1	0	0	0
133	Palangana, *Duval*......	1928	50	0	9,846	0	420	Goliad	5	0	0	0	0
134	Palo Blanco, *Brooks*....	1929	0	80	Gas-spray Oil	Gas	350	Goliad	5	0	0	0	1
135	Patal, *Jim Hogg*.......	1940	0	40	Gas		825*y*	Catahoula	1	0	0	0	0
136	Pena, *Duval*..........	1933	0	40	Gas		580	Goliad	1	0	0	0	0
137	Peters, *Duval*.........	1933	140	1,400	217,424	32,808	795	Catahoula	21	0	0	4	12
138	East Peters, *Duval*.....	1940	60	0	19,589	9,484	650	Catahoula	4	0	0	4	0
139	Petronilla, *Nueces*......	1941	40	0	9,167	9,167	50	Beaumont	2	2	0	2	0
140	Peyote, *Jim Hogg*.....	1932	0	20	Gas		750	Goliad	1	0	0	0	0
141	Piedre Lumbre, *Duval*..	1935	1,280	200	2,652,269	739,762	430	Catahoula	143	8	0	128	4
142	Pietras Pintas, *Duval*...	1905	150	0	154,183	0	450	Goliad	29	0	0	0	0
143	Plymouth, *San Patricio*	1935	3,750	150	22,786,627	2,271,341	55	Beaumont	195	5	1	183	4
144	East Plymouth, *San Patricio*............	1938	0	120	Distillate	Distillate	44	Beaumont	3	0	3	0	0
145	Premont, *Jim Wells*...	1933	720	280	789,391	59,813	205	Lissie	63	3	0	18	3
146	East Premont (Seeligson), *Jim Wells*.....	1937	1,080	200	456,872	217,427	150	Lissie	32	22	5	27	0
147	Ramirez,[10] *Jim Hogg*...	1941	0	20	Gas	Gas	475	Frio	1	1	0	0	0
148	Rancho Solo,[22] *Duval*...	1935	440	160	395,732	86,461	735	Goliad	44	1	0	34	0
149	Randado, *Jim Hogg*...	1926	765	435	4,818,832	81,172	450–500	Catahoula	191	0	0	84	0
150	Reiser,[4] *Webb*.........	1909	20	1,270	4,000	0	700	Jackson	18	0	0	0	0
151	Reynolds, *Jim Wells*...	1939	690	0	943,182	349,026	150	Lissie	32	0	1	26	0
152	Rhode, *McMullen*.....	1936	0	1,200	Gas	Gas	545	Oakville	11	1	0	0	9
153	Ricaby (includes North Ricaby), *Starr*	1937	150	0	121,877	38,788	275	Goliad	14	0	0	9	0
154	Richard King (East Bentonville), *Nueces*.	1937	1,340	140	1,350,462	551,623	130	Beaumont	70	30	2	66	1

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[22] Includes Rancho Solo extension.

TABLE I.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941		Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells								Depth, Avg. Ft.					
	Flowing	Artificial Lift		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
129	12	0		56	Catahoula	Olig	S	Por	3,538	3,548	10	AF	Vicksburg	7,411
				35.6	Frio	Olig	S	Por	5,309	5,444	15			
				57	Frio	Olig	S	Por	6,715	6,720	5			
				38.2–57	Frio	Olig	S	Por	6,900	7,000	15			
130	0	82		22	Mirando	Eoc	S	Por	1,880	2,025	12	ML	Yegua	3,151
				Gas	Cockfield	Eoc	S	Por	2,407	2,473	15			
131	29	0		30.6–32	Frio	Olig	S	Por	5,048	5,125	15	NF	Vicksburg	5,694
132	0	0		Gas	Yegua	Eoc	S	Por	2,924	2,939	15	MF	Yegua	3,008
133	0	0		16	Catahoula	Olig	L	Cav	450	455	5	Ds	Mt. Selman	5,454
				45	Jackson	Eoc	S	Por	2,730	2,744	14			
134	0	0		Gas	Oakville	Mio	S	Por	1,200	1,220	10	Ds	Cockfield	6,603
				Gas—45	Jackson	Eoc	S	Por	4,117	4,150	10			
135	0	0		Gas	Yegua	Eoc	S	Por	3,120	3,130	10	MF	Yegua	3,156
136	0	0		Gas	Frio	Olig	S	Por	1,910	1,932	17	MF	Cockfield	3,620
137	3	1		Gas	Cole	Eoc	S	Por	1,750	1,760	5	ML	Cook Mt.	4,004
				23.1	Govt. Wells	Eoc	S	Por	2,410	2,451	20			
				23.1	Mirando	Eoc	S	Por	2,566	2,635	15			
138	1	3		22.9	Govt. Wells	Eoc	S	Por	2,441	2,465	13	ML	Mirando	2,563
139	2	0		44	Frio	Olig	S	Por	6,952	6,968	10	NF	Frio	7,365
				40	Frio	Olig	S	Por	7,308	7,315	7			
140	0	0		Gas	Govt. Wells	Eoc	S	Por	2,246	2,262	16	ML	Yegua	3,210
141	7	121		20	Cole	Eoc	S	Por	1,324	1,362	7	ML	Yegua	3,400
				21.7–22.7	Govt. Wells	Eoc	S	Por	1,950	2,080	12			
				20.4	Loma Novia	Eoc	S	Por	2,100	2,174	10			
142	0	0		13	Catahoula	Olig	S	Por	180	580	20	Ds	Mt. Selman	5,902
				47	McElroy	Eoc	S	Por	3,462	3,623	26			
143	173	10		31.4	Frio	Olig	S	Por	5,458	5,525	10	AF	Frio	7,253
				34.2	Frio	Olig	S	Por	5,578	5,675	12			
				31.6–62	Frio	Olig	S	Por	5,870	5,920	10			
				40	Frio	Olig	S	Por	6,136	6,159	10			
144	0	0		Gas	Heterostegina	Eoc	S	Por	4,808	4,836	20	AF	Frio	7,287
				Gas	Frio	Olig	S	28–34	5,110	5,136	15			
145	10	8		22.8	Catahoula	Olig	S	Por	2,250	2,350	10	D	McElroy	7,155
				24	Frio	Olig	S	Por	3,165	3,265	11			
				23	Frio	Olig	S	Por	3,706	3,716	10			
146	27	0		39.9	Frio	Olig	S	Por	5,198	5,210	12	A	Vicksburg	8,162
				54–60	Frio	Olig	S	Por	5,365	5,480	10			
				40	Frio	Olig	S	Por	5,555	5,557[21]	2y			
				36–60	Frio	Olig	S	Por	5,625	5,632	10			
				39.9	Frio	Olig	S	Por	5,805	5,850	15			
				40	Frio	Olig	S	Por	5,878	5,988	20			
				39.9	Frio	Olig	S	Por	6,073	6,138	15			
				55	Frio	Olig	S	Por	6,446	6,448[21]	2y			
				38.1	Frio	Olig	S	Por	6,534	6,697	10			
147	0	0		Gas	Mirando	Eoc	S	Por	1,992	2,006	10	ML	Yegua	3,006
148	1	33		19.4	Cole	Eoc	S	Por	1,800	1,895	12	ML	Yegua	3,777
				Gas	Govt. Wells	Eoc	S	Por	2,555	2,569	14			
149	0	84		22.5	Cole	Eoc	S	Por	1,220	1,300	9	NL	Mt. Selman	5,222
150	0	0		16	Jackson-Cockfield	Eoc	S	Por	390	1,010	15	ML	Mt. Selman	3,247
151	23	3		31	Frio[23]	Olig	S	Por	4,753	4,928	10	ANL	Jackson	6,025
				38	Frio	Olig	S	Por	5,100	5,254	9			
152	0	0		Gas	Cole	Eoc	S	Por	1,800	1,822	12	MF	Yegua	3,534
153	3	6		21.2	Frio	Olig	S	Por	1,270	1,324	8	NL	Jackson	2,844
				21.2	Frio	Olig	S	Por	1,432	1,456	5			
				30	Frio	Olig	S	Por	1,604	1,611	7			
154	66	0		22	Heterostegina	Olig	S	Por	3,800	4,030	15	AF	McElroy	7,567
				37	Frio	Olig	S	Por	5,250	5,270	7			
				39	Frio	Olig	S	Por	5,380	5,466	15			
				42	Frio	Olig	S	Por	5,595	5,750	10			
				38	Vicksburg	Olig	S	Por	6,133	6,143	10			
				56	Vicksburg	Olig	S	Por	6,230	6,235	5			

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[21] Perforations.

[23] One well produces oil from Frio sand at 3145 ft.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	During 1941	End of 1941		
										Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
155	Rincon, *Starr*.........	1938	3,175	280	1,877,039	948,854	460	Goliad	126	71	7	119	0
156	North Rincon, *Starr*....	1940	220	40	89,111	81,677	440	Goliad	13	9	2	10	0
157	Rio Grande City, *Starr*.	1932	200	60	440,722	40,380	180	Catahoula	34	4	0	20	0
158	Rios, *Duval*...........	1941	0	20	*y*	*y*		Goliad	1	1	1	0	0
159	Riverside, *Nueces*......	1938	80	80	87,167	26,747	35	Beaumont	6	1	2	2	1
160	Robston, *Nueces*.......	1939	60	0	66,899	28,376	88	Beaumont	3	1	0	3	0
161	Roma, *Starr*..........	1927	20	280	22,306	898	285	Jackson	6	0	0	1	5
162	Sacatosa, *Starr*........	1938	0	20	Gas		349	Frio	1	0	0	0	0
163	Sam Fordyce,[24] *Starr, Hidalgo*............	1934	1,600	900	8,082,693	268,411	170–250	Goliad	259	3	0	81	2
164	Sandia, *Jim Wells*.....	1929	80	400	23,432	713	150	Lissie	9	3	3	2	0
165	San Diego, *Jim Wells*..	1934	0	320	Gas		290	Lissie	2	0	0	0	0
166	San Jose, *McMullen*...	1938	10	10	450	0	387	Catahoula	2	0	0	0	0
167	San Salvador,[25] *Hidalgo*	1938	0	1,200	111,804*y*	*y*	88	Beaumont	5	0	5	0	0
168	Santo Domingo, *Starr*..	1936	0	120	Gas		150	Alluvium	2	0	0	0	0
169	Sarnosa, *Duval*........	1932	690	180	2,552,017	159,161	735	Catahoula	57	0	0	37	0
	Saxet, *Nueces*.........	1923					20–80	Beaumont					
170	Shallow..........	1923	3,850	3,800	28,048,184	2,495,637	20–80	Beaumont	761	2	13	304	43
171	Deep (Frio).......	1935	2,450	3,400	22,769,238	1,550,908		Beaumont			38	107	18
172	Seabury (Zim), *Starr*...	1939	10	10	722	238		Catahoula	2	0	0	1	0
173	Sejita, *Duval*..........	1939	0	240	3,400	1,600	330	Goliad	6	2	6	0	0
174	Seven Sisters, *Duval*...	1934	4,420	280	16,285,471[26]	2,724,188	460–520	Catahoula	458	2	0	391	7
175	South Seven Sisters, *Duval.*	1937	330	0	See Seven Sisters	76,027	575	Catahoula	33	0	0	31	0
176	Shield, *Nueces*.........	1940	200	60	108,046	86,259	65	Beaumont	13	9	1	9	3
177	Sinton, *San Patricio*....	1934	225	100	86,445	610	70	Beaumont	7	0	1	0	0
178	Southland, *Duval*......	1939	80	20	109,023	32,375	401	Goliad	5	0	1	3	0

[24] Includes North Sam Fordyce.

[25] Includes figures for Las Mestenas.

[26] Includes South Seven Sister total production.

TABLE 1.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941		Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells			Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
	Flowing	Artificial Lift							Top Prod. Zone	Bottoms Prod. Wells				
155	119	0		38.7	Frio	Olig	S	Por	3,629	3,797	20	A	Yegua	6,862
				44	Frio	Olig	S	Por	3,855	4,046	18			
				45.1	Frio-Vicksburg	Olig	S	26–39	4,116	4,294	20			
156	7	3		44.6	Frio	Olig	S	Por	4,111	4,212	18	A	Jackson	5,590
				42.5	Vicksburg	Olig	S	Por	4,370	4,402	9			
				52	Vicksburg	Olig	S	Por	4,632	4,670	15			
				41.9	Vicksburg	Olig	S	Por	4,725	4,745	15			
				47.5	Jackson	Olig	S	Por	5,478	5,590	15			
157	0	20		23	Frio	Olig	S	Por	1,350	1,450	8	MFL	Yegua	3,258
158	0	0		51.2	McElroy	Eoc	S	Por	6,270	6,308	15	NFy	McElroy	6,308
159	2	0		32.2	Frio	Olig	S	Por	4,888	5,037	25	A	Vicksburg	7,750
				55	Frio	Olig	S	Por	6,970	6,975	5			
160	3	0		41.9	Frio	Olig	S	Por	5,195	5,208	12	A	Frio	7,525
				51.9	Frio	Olig	S	Por	5,548	5,650	20			
161	1	0		Gas	Jackson	Eoc	S	Por	192	200	8	A	Reklaw	4,827
				35.2	Queen City	Eoc	S	Por	3,560	3,650	6			
162	0	0		Gas	Govt. Wells	Eoc	S	Por	1,650	1,661	11	ML	Govt. Wells	1,794
163	10	71		21.5	Frio	Olig	S	Por	2,737	2,793	16	AF	Mt. Selman	9,708
				24.9	Frio	Olig	S	Por	2,831	2,890	22			
				24.9	Frio	Olig	S	Por	2,925	3,125	20			
				Gas	Frio	Olig	S	Por	3,183	3,196	13			
				Gas	Jackson	Eoc	S	Por	5,840	5,900	20			
164	0	2		Gas	Catahoula	Olig	S	Por	2,910	2,917	7	AF	McElroy	5,701
				38.3	Frio	Olig	S	Por	4,002	4,023	13			
				52	Cole	Eoc	S	Por	5,151	5,163	10			
165	0	0		Gas	Frio	Olig	S	Por	2,952	2,976	10	A	Yegua	6,480
166	0	0		23	Cole	Eoc	S	Por	1,147	1,163	16	ML	Yegua	2,370
167	0	0	PM	48.8–58	Frio	Olig	S	Por	7,315	7,645	15	A	Vicksburg	8,704
				49.7	Frio-Vicksburg	Olig	S	Por	8,174	8,704	15			
168	0	0		Gas	Frio	Olig	S	Por	2,461	2,616	25	A	Cook Mt.	6,005
169	0	37		21.3	Govt. Wells	Eoc	S	Por	2,300	2,500	15	MF	Yegua	4,073
									1,000	9,927				
170	108	196		24	Largarto-Oakville	Plio-Mio	S	Por	1,000	3,150	15	DF	Vicksburg	10,892
				24	Catahoula	Olig	S	29–42	3,900	4,500	18			
				31.7	Discorbis-Het.	Olig	S	Por	4,700	4,880	18			
171	44	63		30.6–42.6	Frio	Olig	S	7–45	5,280	6,900	20			
				56	Frio	Olig	S	Por	7,250	7,548	20			
				58	Frio-Vicksburg	Olig	S	Por	9,900	9,927	20			
172	1	0		24	Frio	Olig	S	Por	1,328	1,339	5	MF	Yegua	2,757
173	0	0		51.7	McElroy	Eoc	S	Por	5,334	5,395	15	AF	Yegua	7,095
				52	McElroy	Eoc	S	Por	5,476	5,675	15			
				54	McElroy	Eoc	S	Por	5,770	5,830	20			
174	4	387		Gas	Frio	Olig	S	Por	1,232	1,262	15	AF	Cook Mt.	4,404
				21	Cole	Eoc	S	Por	1,710	1,720	10			
				20.9	Chernosky	Eoc	S	Por	2,112	2,225	20			
				23	Govt. Wells	Eoc	S	Por	2,470	2,500	15			
				27	Loma Novia[27]	Eoc	S	Por	2,660	2,690	15			
				23	Mirando	Eoc	S	Por	2,540	2,565	10			
				Gas	Yegua	Eoc	S	Por	3,037	3,071	15			
175	0	31		21.5	Frio	Olig	S	Por	1,487	1,566	7	AF	Yegua	3,100
				23	Loma Novia	Eoc	S	Por	2,643	2,656	10			
176	9	0		44.3	Frio	Olig	S	Por	6,602	6,657	15	AF	Frio	7,806
				56	Frio	Olig	S	Por	6,970	6,980	10			
177	0	0		33.4–47	Frio	Olig	S	Por	5,408	5,641	15	A	Frio	7,438
				33	Frio	Olig	S	Por	5,880	5,905	10			
178	3	0		48.1	Pettus	Eoc	S	Por	5,286	5,298	10	AFL	Yegua	6,015
				43.8	Pettus	Eoc	S	Por	5,355	5,365	10			

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[27] Stratigraphically higher than Mirando. Variance in depth due to surface elevations.

TABLE 1.—(*Continued*)

Line Number	Field County	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Surface Data		Number of Oil and/or Gas Wells				
			Oil	Distillate and/or Gas[b]	To End of 1941	During 1941	Average Elevation, Feet	Surface Formation	Completed to End of 1941	During 1941	End of 1941		
										Completed	Producing Distillate and Gas	Producing Crude Oil[c]	Producing Only Gas[c]
179	Stratton, *Nueces, Kleburg, Jim Wells*.....	1931	1,650	2,350	1,060,601	597,783	100	Beaumont	112	72	28	82	0
180	Sullivan (South Agua Dulce), *Nueces*......	1936	Included in Agua Dulce				50	Beaumont	See Agua Dulce				
181	Sullivan City, *Hidalgo, Starr*...............	1939	780	160	337,795	247,739	220	Goliad	39	13	4	34	0
182	Sun, *Starr*............	1938	1,400	100	853.495	421,559	366	Goliad	75	24	3	70	1
183	North Sun, *Starr*......	1941	20	0	668	668	312	Goliad	1	1	0	1	0
184	Sun-Jones,[10] *Jim Hogg*.	1941	0	20	Gas	Gas	525	Goliad	1	1	0	0	1
185	Sweden, *Duval*........	1937	200	160	238,770	17,514	380	Goliad	15	2	1	5	0
186	Taft, *San Patricio*.....	1935	720	80	4,900,282	607,992	50	Beaumont	74	0	1	69	1
187	Tarancahuas, *Duval*....	1939	290	0	301,208	183,051	585	Goliad	29	0	0	29	0
188	Tesoro (De Soto), *Duval*	1938	140	80	198,675	30,785	440	Goliad	8	0	1	3	0
189	Thomas Lockhart, *Duval*...............	1937	100	0	17,146	0	500	Lagarto-Gol.	4	0	0	0	0
190	Turkey Creek (West Saxet), *Nueces*......	1938	890	40	3,688,120	612,134	60	Beaumont	60	0	1	57	1
191	Villa, *Zapata*..........	1932		120	Gas	0	670	Frio	3	0	0	0	0
192	Volpe, *Webb*..........	1939	330	10	353,022	179,993	761	Goliad	34	0	0	28	0
193	Wade City, *Jim Wells*.	1939	2,000	200	1,763,512	1,112,014	200	Lissie	104	24	5	96	3
194	Washburn, *LaSalle*....	1940	120	0	13,755	10,405	440	Yegua	3	2[28]	0	3	0
195	Wentz, *McMullen*.....	1932	0	80	Gas	0	200	Frio-Jack.	3	0	0	0	0
196	Weslaco, *Hidalgo*......	1938	0	40	2,125*y*	*y*	82	Beaumont	1	0	1	0	0
197	White Point, *San Patricio*...............	1911	100	3,900	159,683	12,041	60	Beaumont	48	0	1	1	9
198	East White Point, *San Patricio, Nueces*.....	1938	4,360	180	8,302,052	2,869,094	56	Beaumont	246	11	2	238	4
199	Willamar, *Willacy*.....	1940	100	0	47,555	2,939	15	Alluvium	5	4	0	5	0
200	Woods, *Starr*..........	1936	0	120	Gas	0	190	Goliad	4	0	0	0	0
201	Wray, *Zapata*.........	1933	0	80	Gas	0	498	Jackson	3	0	0	0	0
202	Young (Charco Blanco), *Starr*...............	1938	0	20	Gas	Gas	374	Goliad	1	0	0	0	1
203	Yturria, *Starr*.........	1941	80	0	2,507	2,507	360	Goliad	4	4	0	4	0
204	Yzaguirre, *Starr*.......	1940	20	20	4,948	2,634	400	Goliad	2	0	0	1	0
205	Total............		127,900	83,120	377,508,915	50,511,866			13,234	1,014	411	8,347	452

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[28] Includes one re-completion.

TABLE 1.—(*Continued*)

Line Number	Crude-oil-production Methods, End of 1941		Repressuring Operation[d]	Character of Oil	Producing Formation								Deepest Zone Tested to End of 1941	
	Number of Wells								Depth, Avg. Ft.					
	Flowing	Artificial Lift		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
179	82	0	PM	58	Frio	Olig	S	Por	4,788	4,924	15	AF	Vicksburg	8,138
				49.3	Frio	Olig	S	Por	5,992	6,002	10			
				43–54	Frio	Olig	S	Por	6,273	6,460	20			
				54	Frio	Olig	S	Por	6,480	6,607	17			
				43	Frio	Olig	S	Por	6,658	6,770	20			
				54	Frio	Olig	S	Por	6,804	6,823	15			
180				51	Frio	Olig	S	Por	5,756	5,780	15	AF	Frio	6,912
				Gas-dist.	Frio	Olig	S	Por	6,400	6,668	15			
				Gas-dist.	Frio	Olig	S	Por	6,788	6,800	12			
181	30	4		24	Frio	Olig	S	Por	3,414	3,463	15	AF	Mt. Selman	9,708
				39.4	Frio	Olig	S	Por	3,936	3,983	25			
				43.6	Frio	Olig	S	Por	4,121	4,130	9			
182	67	3		52	Frio	Olig	S	Por	4,111	4,142	15	A	Jackson	6,113
				47	Frio	Olig	S	Por	4,500	4,565	20			
				46–62	Frio	Olig	S	Por	4,610	4,673	15			
				45.2	Frio	Olig	S	Por	4,842	4,858	16			
				45.1	Frio	Olig	S	Por	4,900	4,972	10			
				47.9	Vicksburg	Olig	S	Por	5,115	5,135	20			
183	1	0		46.7	Vicksburg	Olig	S	Por	5,376	5,396	20	A	Jackson	
184	0	0		Gas	Jackson	Eoc	S	Por	4,211	4,268	15	ML y	Yegua	6,009
185	2	3		43	Chernosky	Eoc	S	Por	4,895	4,939	20	AF	Yegua	7,005
				46	Upper Govt. Wells	Eoc	S	Por	5,072	5,091	19			
				Gas	Lower Govt. Wells	Eoc	S	Por	5,100	5,116	16			
				43	Cockfield	Eoc	S	Por	5,845	5,869	24			
186	47	22		21.4	Catahoula	Olig	S	Por	3,975	4,010	20	MF	Frio	6,926
				21.6	Catahoula	Olig	S	Por	4,300	4,375	20			
				23	Heterostegina	Olig	S	Por	4,900	4,938	20			
187	1	28		21.1	Frio	Olig	S	Por	2,014	2,105	15	NL	Yegua	3,461
188	3	0		Gas	Pettus	Eoc	S	Por	4,828	4,848	15	NF	Yegua	5,541
				41.8–45	Yegua	Eoc	S	Por	5,080	5,136	20			
189	0	0		56.8	Pettus	Eoc	S	Por	4,659	4,672	13	MF	Yegua	5,502
190	39	18		22.6	Catahoula	Olig	S	Por	3,840	3,860	14	DF	Frio	7,511
				25	Catahoula	Olig	S	Por	4,025	4,080	10			
				43	Frio	Olig	S	Por	5,641	5,664	19			
				35	Frio	Olig	S	Por	5,787	5,872	19			
				28	Frio	Olig	S	Por	6,430	6,456	26			
191	0	0		Gas	McElroy	Eoc	S	Por	1,650	1,664	7	ML	Cook Mt.	3,000
192	0	28		22.5	Mirando	Eoc	S	Por	2,450	2,488	10	MF		
193	88	8		50	Frio	Olig	S	Por	3,283	3,302	15	NF	Jackson	5,415
				31–51	Frio	Olig	S	Por	4,763	4,820	10			
				32.2	Vicksburg	Olig	S	Por	4,894	4,933	10			
				55	Vicksburg	Olig	S	Por	5,272	5,286	12			
194	2	1		42	Wilcox (Rockdale)	Eoc	S	25	4,822	4,867	15	AF	Cretaceous	11,042
				40.5	Wilcox (Rockdale)	Eoc	S	22.5	5,413	5,430	15			
				40.3	Wilcox (Rockdale)	Eoc	S	Por	5,513	5,578	20			
195	0	0		Gas	Cole	Eoc	S	Por	370	382	12	NL	Yegua	1,654
196	0	0		51	Frio	Olig	S	Por	8,634	9,005	15	A	Vicksburg	9,182
197	0	1		Gas	Lagarto-Oakville	Mio	S	Por	1,900	2,800	10	AF	Frio	7,211
				24.8	Heterostegina	Olig	S	Por	4,880	4,961	10			
				29.8	Frio	Olig	S	Por	5,672	5,676	4			
198	234	4		Gas	Oakville	Mio	S	Por	2,495	2,505	10	AF	Frio	8,483
				Gas	Catahoula	Olig	S	Por	3,960	4,100	10			
				26.8	Heterostegina	Olig	S	Por	4,930	4,952	20			
				38.7	Frio	Olig	S	24–33	5,630	5,680	30			
				59.4	Frio	Olig	S	Por	5,730	5,775	15			
				40.4	Frio	Olig	S	Por	5,850	5,862	12			
199	5	0		30	Frio	Olig	S	Por	7,620	7,678	15	A	Frio	9,003
				30	Frio	Olig	S	Por	7,847	7,880	20			
				30.4	Frio	Olig	S	Por	7,925	7,970	25			
200	0	0		Gas	Frio	Olig	S	Por	963	975	12	A	Jackson	3,360
201	0	0		Gas	Jackson	Eoc	S	Por	348	370	22	ML	Cook Mt.	2,003
202	0	0		Gas	Mirando	Eoc	S	Por	2,708	2,730	15	MF	Cockfield	3,008
203	4	0		43.3	Frio	Olig	S	Por	4,232	4,248	5	MF	Jackson	4,889
204	0	1		48.1	Frio	Olig	S	Por	4,610	4,620	10	A	Jackson	6,006
				56	Vicksburg	Olig	S	Por	5,234	5,246	12			
205	2,908	5,439												

tillate wells, 66 gas producers, and 213 dry holes (Table 4).

The decrease of activity in some large fields, together with the lack of development of new areas discovered during the year, accounts for much of the decrease in the total number of well completions. In several fields, however, there was extensive development, and, besides the discovery of new producing levels, important extensions were made by semiwildcat wells. The most active fields were: Casa Blanca and Charamousca, Duval County; Colorado, Jim Hogg County; Rincon and Sun, Starr County; Kelsey, in Starr, Brooks and Jim Hogg Counties; Killam and Glen, Webb County; Agua Dulce, Stratton, Clara Driscoll (including South Clara Driscoll), Minnie Bock and Richard King fields, Nueces County; Midway, San Patricio County, and East Premont (Seeligson) and Wade City, Jim Wells County. All of these are fields discovered prior to 1941, none of the new fields having been subjected to important development.

Probably the most significant development of the year was the discovery of very large reserves of crude oil on the east flank of the Agua Dulce and Stratton fields, Nueces County. By a drilling program that led to a series of important extensions, these two fields, which formerly produced distillate and gas, have been joined to form one great producing area that now extends approximately 17 miles northeast-southwest and is about 5 miles wide. Crude production on the west flank of Agua Dulce was opened late in the year. The East Premont (Seeligson), La Gloria, and Odem fields were also proved to be important crude as well as distillate and gas reserves, by similar flank developments. The La Reforma structure of Starr County produced crude in a well on its northeast flank; wells higher on the structure produce only distillate and gas. Future discoveries of this type are to be expected, since results already obtained are certain to stimulate interest in possible crude accumulation on the flanks of other South Texas anticlinal and domal distillate-and-gas or gas-producing structures.

Cenozoic Sediments in the Texas Coastal Region

Cenozoic sediments offer great opportunities for production from stratigraphic and sedimentary traps in South Texas; therefore the following notes are included to emphasize the importance of a method of geological exploration that is likely to be the key to the problem of the discovery of sufficient national oil reserves. Based on an extensive knowledge of the detailed aspects of sedimentation, this relatively new trend in prospecting for oil and gas should not be overlooked in the selection of drilling sites for wells seeking new reserves.

Cenozoic sediments of the Texas Coastal region already account for an important part of the nation's petroleum production and reserves. These sediments consist chiefly of shales, clays, and sands that by crustal disturbances and the movements of salt domes, have been locally uplifted or faulted into relationships favorable to the commercial accumulations of oil and gas. Some of these petroliferous areas have been relatively easily discovered through surface indications or because of their proximity to the surface; but the search for the deeper, less obvious structures has necessitated the introduction of several prospecting methods, which have been responsible for the discovery of many structural fields. In addition to these, however, many reservoirs have been discovered whose occurrence can be attributed to purely stratigraphic or sedimentary conditions, the former having reference to vertical and the latter to horizontal components within the substrata. Discovery of these traps usually has been accomplished by detailed geological study of the area involved, or by chance drilling.

The abundance of potentially productive sand bodies, the great complexity of Cenozoic sedimentation, and the further dislocation of beds by crustal movements that followed their deposition indicate a prolific future for the Texas Coastal area. As the structural fields are discovered, and accordingly grow scarcer, the hidden petroleum traps that owe their existence to stratigraphic and sedimentary conditions will become increasingly the object of the oil industry's search—a search that to a great degree must fall on the shoulders of the petroleum geologist.

General Classification of Stratigraphic Divisions of the Cenozoic

Age	Group	Formation	Member (South Texas)	Relative Positions of Producing Sands of Jackson and Upper Yegua
Pleistocene	Houston	Beaumont Lissie	Undivided Undivided	
Pliocene	Citronelle	Goliad (Reynosa)	Labahia Lagarto Creek Lapara	
Pliocene-Miocene	Fleming	Lagarto Oakville	Undivided Undivided	
Oligocene(?)	Gueydan	Catahoula	Chusa Soledad Fant	
Oligocene		Subsurface Marine Oligocene	Discorbis Heterostegina Marginulina	
		Frio Vicksburg (Sub-surface)	Undivided	
Eocene	Jackson	Fayette	Whitsett	
			McElroy (Hockleyensis)	Cole sand Chernosky sand Government Wells sands Loma Novia sand Upper Mirando sand
			Caddell (Diboll)	Lower Mirando sand O'Hern sand
	Claiborne Cook Mountain	Yegua	Cockfield*	Pettus sands (upper Yegua)
		Crockett	Undivided	
		Sparta	Undivided	
		Weches	Undivided	
	Mount Selman	Queen City	Undivided	
		Reklaw	Undivided	
		Carrizo	Undivided	
	Wilcox	Sabinetown	Undivided	
		Rockdale	Undivided	
		Seguin	Caldwell Knob Solomon Creek	
	Midway	Wills Point Kincaid	Pisgah Littig	

* Nonionella beds of Upper Cockfield have been demonstrated to be Jackson in age.

Cenozoic strata of Texas (see classification herewith) present as yet an incompletely deciphered picture of an age-old feud between the forces of the sea and the forces of the land, each attempting to encroach upon the other. For long alternating periods one or the other force predominated, but not without opposition—every major sea encroachment involved a number of minor regressive and transgressive oscillations, and every major gain by the streams and swamps of the land was at the cost of major recession by marine waters. This long and continuous battle brought about a great complexity in the stratigraphy and sedimentation of the Coastal area. Both vertically and horizontally, there are sudden and gradual changes from continental to marine facies. Numerous shore lines exist, and the wedging or pinching out of beds is a frequent occurrence; the latter condition, especially

TABLE 2.—*Summary of Drilling Operations in South Texas*

Important Wildcats and Semiwildcats Drilled in 1941

	District and County	Well Name and Location	Total Depth, Ft. or Meters	Surface Formation	Deepest Horizon Tested
	LAREDO DISTRICT				
1	Duval	Parr-No.1, blk. 18, Callaghan subd. (Benavides field)	5,025	Goliad	Yegua
2	Duval	Geo. Parr No. 1-A, 1½ m. E. of Benavides field	5,040	Goliad	Govt. Wells
3	Duval	Lopez No. 1, sec. 455	1,705	Goliad	Cole
4	Duval	C. Gonzales No. 1, Carrera survey	6,308	Goliad	Hockleyensis
5	Duval	Parr No. 30 (Benavides field)	5,995	Goliad	Yegua
6	Duval	Parr No. 31 (Benavides field)	5,749	Goliad	Yegua
7	Duval	Escapole No. 1-B (Kries field)	3,212	Catahoula	Loma Novia
8	Duval	Cuellar No. 5 (Hoffman field)	3,152	Catahoula	Pettus
9	Duval	Herberger No. 6 (Sweden field)	4,940	Goliad	Jackson
10	Duval	A. Labbe No. 3 (Labbe field)	2,930	Goliad	Hockleyensis
11	Duval	Wiederkehr No. 75, sec. 55	2,940	Catahoula	Yegua
12	Duval	Casey No. 2 (Sejita field)	5,785	Goliad	Jackson
13	Duval	Yzaguirre No. 1 (Sejita field)	5,547	Goliad	Hockleyensis
14	Jim Hogg	Ramirez No. 1, survey 271	3,006	Catahoula	Yegua
15	Jim Hogg	Bute No. 2, blk 282, Pippin subd. Randado grant	3,465	Catahoula	Yegua
16	Jim Hogg	C. Palacios No. 1, sec. 287	3,008	Catahoula	Yegua
17	Jim Hogg	Jones No. 1, Agua Neuva de Abajo grant	6,009	Goliad	Vicksburg
18	Jim Hogg	East No. 1, El Randado grant	3,469	Catahoula	Yegua
19	Jim Hogg	McLean No. 2 (Holbein field)	2,810	Goliad	Pettus
20	Jim Hogg	McLean No. 1 (Holbein field)	2,808	Goliad	Pettus
21	Jim Hogg	Gallagher No. 2 (Chaparosa field)	3,071	Catahoula	Jackson
22	La Salle	Washburn No. 1 (Washburn field)	8,300	Yegua	Cretaceous
23	La Salle	Washburn No. 4 (Washburn field)	5,700	Yegua	Wilcox
24	La Salle	Washburn No. 3-A (Washburn field)	11,042	Yegua	Cretaceous
25	McMullen	Edrington No. 1-I, survey 61	3,023	Goliad	Pettus
26	McMullen	Edrington No. 3-I (So. Campana)	2,573	Goliad	Govt. Wells
27	McMullen	Ezzell No. 44 (So. Calliham)	1,546	Jackson	Pettus
28	McMullen	Ferguson No. 1 (So. Campana)	3,135	Goliad	Pettus
29	Starr	C. M. Hall No. 1 (North Rincon)	5,478	Goliad	Jackson
30	Starr	Yturria L. & L. Co. No. 1, Porc. 100	4,889	Goliad	Jackson
31	Starr	M. M. Garcia No. 1 (Boyle field)	3,476	Goliad	Frio
32	Starr	Slick No. 20-A (Rincon field)	5,673	Goliad	Jackson
33	Starr	A. Guerra-No. 1 (La Reforma field)	6,198	Goliad	Vicksburg
34	Starr	Montalvo No. 1-C (Sun field)	6,607	Goliad	Jackson
35	Starr	Davenport 1-D (Rincon field)	4,689	Goliad	Vicksburg
36	Starr	Coates No. 1 (No. Rincon field)	5,213	Goliad	Jackson
37	Starr	E. Trevino No. 1-B (Kelsey field)	4,764	Goliad	Frio
38	Starr	Slick No. 95-B (Rincon field)	4,433	Goliad	Vicksburg
39	Starr	Slick No. 51-B (Rincon field)	4,613	Goliad	Vicksburg
40	Starr	Chapotal No. 1 (Yturria field)	4,236	Goliad	Frio
41	Starr	Garcia L. & L. Co. No. 1 (Sullivan City)	4,306	Goliad	Frio
42	Starr	Saenz-State No. 4 (North Rincon)	4,745	Goliad	Frio
43	Starr	Olivarez No. 2 (Sun field)	y	Goliad	y
44	Webb				
45	Zapata	Garcia No. C-5 (Escobas)	448	Jackson	Jackson
46	Zapata	Ramirez No. 1-B (Lopena)	3,100	Yegua	Reklaw
47	Zapata	Ramirez No. 1 (Lopena)	2,555	Yegua	Queen City
	SOUTH CORPUS CHRISTI DISTRICT				
48	Brooks	McGill Bros. No. 81 (Kelsey field)	4,945	Sand dunes	Frio
49	Brooks	Riley No. 1 (La Gloria field)	6,798	Lissie	Frio
50	Brooks	Arguilles No. 1 (La Gloria field)	6,650	Lissie	Frio
51	Brooks	South Unit No. 1 (La Gloria field)	6,900	Lissie	Frio
52	Hidalgo	Yturria No. 1-C (Nichols)	3,960	Goliad	Frio
53	Hidalgo	Yturria No. D-4 (Nichols)	3,927	Goliad	Frio
54	Hidalgo	Yturria No. B-1 (Nichols)	3,955	Goliad	Frio
55	Hidalgo	Arizona-Texas Citrus No. 1 (McAllen)	8,513	Beaumont	Vicksburg
56	Jim Wells	Adams No. 1—R. Adams survey	5,185	Lissie	Jackson
57	Jim Wells	Seeligson Unit 4—No. 1, sec. 68	5,038	Lissie	Frio
58	Jim Wells	Seeligson No. 15 (Seeligson)	5,903	Lissie	Frio
59	Jim Wells	Seeligson No. 16 (Seeligson)	6,626	Lissie	Vicksburg
60	Jim Wells	Seeligson No. 17 (Seeligson)	6,856	Lissie	Vicksburg
61	Jim Wells	Canales No. 1 (Seeligson)	5,210	Lissie	Frio

TABLE 2.—(*Continued*)

Important Wildcats and Semiwildcats Drilled in 1941

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	E. R. Thomas Estate	52.4	Gas	7/32	1,180	1,000	Opened Agua Prieta field
2	Hiawatha Oil & Gas	169		1/4	1,000	200	Opened East Benavides field
3	Henderson, Coquat	100			Swabbed		Opened Coquat-Lopez field
4	Argo Oil Co.	34	7	1 1/4 pipe	2,700 (shut-in)		Opened Rios field
5	Hiawatha Oil & Gas	25	5		1,950	1,825	2000-ft. east extension
6	Hiawatha Oil & Gas	100	20				New 5700-ft. Yegua sand
7	Bridwell Oil Co.	148		1/4	240	90	SW. extension
8	Cox & Hamon	91			On pump		New 3100-ft. Pettus sand
9	Hiawatha Oil & Gas Co.	220		1/4	1,740	1,170	New 4900-ft. Jackson sand
10	Butler, Carter & Douglas	Spray	0.75	3/16		625	New 1800-ft. Frio sand
11	Sun Oil Co.	86		3/16	585	80	Opened Govt. Wells Yegua field
12	Trinity Gas Co.	200	35		2,100 (shut-in)		3/4 mile west ext. new 5700-ft. sand
13	Trinity Gas Co.	250	50				1 mile east extension new 5300-ft. sand
14	Forest Development Co.		7		600 (shut-in)		Opened Ramirez field
15	Neuhaus & Lucky		2.5	1/8	1,100 (shut-in)		Opened Chaparosa field
16	Bidrich Oil Co.	Spray	10	1/8	1,050	985	Opened Palacios field
17	Sun Oil Co.		20	5/32	1,500	1,500	Opened Sun-Jones field
18	Adams, Lucky, Neuhaus	102		1/4	350	200	
19	M. L. Massingill	75			On pump		North extension
20	M. L. Massingill	77			On pump		North extension
21	Neuhaus, Adams, Lucky		2.5		975	850	New 2700-ft. sand
22	Quintana Petr. Co.	65			On pump		Recompletion in new 5400-ft. sand
23	Quintana Petr. Co.	406	20	1/4	1,350	1,180	1 1/4 mile SW. extension new 5500-ft. Wilcox sand
24	Quintana Petr. Co.						Dry deep test
25	Argo Oil Co.	157		1 1/4	740		Opened South Campana field
26	Argo Oil Co.		8	3/32	900	900	Opened 2500-ft. Govt. Wells sand
27	Harry Ezzell		3				1 1/2 mile SW. extension
28	Transwestern Oil Co.	8	4	7/16	1,010	950	1 1/2 mile SW. extension
29	Sun Oil Co.		1.042	5/32	1,800	1,600	New 4600-ft. Frio sand
30	Sun Oil Co.	21		7/64	1,500	1,200	Opened Yturria field
31	Dean & Hendrickson	35	4	5/64	1,200	800	1 mile NW. extension new 2800-ft. Frio sand
32	Continental Oil Co.	82	Gas	3/16	210 (working)		Southeast extension
33	Porter & Pickens	168		1/8	800	600	First Crude, new 6100-ft. sand
34	Sun Oil Co.	154		7/64	2,060	1,485	New 5300-ft. Vicksburg sand
35	Continental Oil Co.	69			(Jetting)		1 1/2 mile south extension
36	Sun Oil Co.	233		1/4			West extension
37	Sun Oil Co.	187		5/32	940	720	1 mile south extension
38	Continental Oil Co.	176		3/16	650	440	1 mile south extension
39	Continental Oil Co.	52		3/16	1,550	1,425	1 1/4 mile SW. extension
40	Sun Oil Co.	143		9/64	755	580	1 mile NW. extension
41	Complete Oil Well Svc. Co.		10	3/8	850 (working)		1 mile NW extension
42	Sun Oil Co	134					New 4700-ft. Frio sand
43	Circle Oil Co.	13					New 4500-ft. Frio sand
44							
45	Dulup Oil Co.	5			On pump		New 400-ft. Jackson sand
46	Venture Petr. Co.		Gas				New 2400-ft. Queen City sand
47	American-Texas Oil Co.		Gas				New 2500 ft. Queen City sand
48	Humble Oil & Ref. Co.	166		9/64	1,050	800	New 4900-ft. Frio sand
49	La Gloria Oper. Committee	250	200		3,050 (shut-in)		3500-ft. SE. extension
50	La Gloria Oper. Committee	300	100				4800-ft. SE. extension
51	La Gloria Oper. Committee	500	150				1 mile SW. extension
52	Baldridge & King	110		1/8	675	550	New 3600-ft. Frio sand
53	Baldridge & King	116		1/8	650	400	New 3900-ft. Frio sand
54	Baldridge & King	88					New 3800-ft. Frio sand
55	W. R. Davis	100	21.5	5/8	3,030	3 000	7250-ft. SE. extension new 7500-ft. Frio sand
56	Howeth & Wilcox	147		1/4	1,500	520	Opened New West Alfred field
57	Magnolia Petr. Co.	106		1/8	1,725	700	Opened Haldeman field
58	Magnolia Petr. Co.	167		5/32	1,000	900	NW. extension new 5800-ft. Frio sand
59	Magnolia Petr. Co.	40	3.7				New 6400-ft. Frio sand
60	Magnolia Petr. Co.	125		1/8	1,000	570	New 5500-ft. Frio sand
61	Sun Oil Co.	173		1/4	1,175	220	1 mile west extension new 5100-ft. Frio sand

TABLE 2.—(*Continued*)

Important Wildcats and Semiwildcats Drilled in 1941

	District and County	Well Name and Location	Total Depth, Ft. or Meters	Surface Formation	Deepest Horizon Tested
62	Jim Wells	Dunlap No. 2 (Seeligson)	6,796	Lissie	Vicksburg
63	Jim Wells	Dunlap No. 3 (Seeligson)	6,276	Lissie	Frio
64	Jim Wells	Scott No. 1 (La Gloria)	6,764	Lissie	Frio
65	Jim Wells	N. Lafferty No. 1 (La Gloria)	6,902	Lissie	Frio
66	Jim Wells	La Gloria No. 14 (La Gloria)	6,900	Lissie	Frio
67	Jim Wells	D. O. Maun No. 2 (La Gloria)	6,901	Lissie	Frio
68	Jim Wells	Conkle No. 1 (La Gloria)	7,500	Lissie	Vicksburg
69	Jim Wells	Isham No. 1 (Premont)	3,936	Lissie	Frio
70	Jim Wells	Adams No. 2 (West Alfred)	4,390	Lissie	Frio
71	Jim Wells	B. H. Mueller No. 1 (Wade City)	5,100	Lissie	Vicksburg
72	Jim Wells	Fee No. 1-H (Henshaw)	5,800	Lissie	Jackson
73	Jim Wells	Cumings Estate No. 1 (Alice)	5,212	Lissie	Frio
74	Jim Wells	Wardner No. 23 (Stratton)	6,702	Beaumont	Frio
75	Kleburg	Wardner No. 20 (Stratton)	7,200	Beaumont	Frio
76	Nueces	J. T. Gillette No. 1, C.D.C survey	7,315	Beaumont	Frio
77	Nueces	Burow No. 1, V. L. de Herrera grant	7,512	Beaumont	Frio
78	Nueces	Wolter No. 1 (Agua Dulce)	6,945	Beaumont	Frio
79	Nueces	J. R. Knight No. 1 (Petronilla)	7,365	Beaumont	Frio
80	Nueces	Grove No. 1 (Banquette)	7,538	Beaumont	Frio
81	Nueces	Pfluger No. 2 (Agua Dulce)	7,143	Beaumont	Frio
82	Nueces	Luby No. 9 (Luby field)	7,313	Beaumont	Frio
83	Nueces	Bush-Wofford No. 1 (Agua Dulce)	7,210	Beaumont	Frio
84	Nueces	Pfluger No. 1-B (Agua Dulce)	7,161	Beaumont	Frio
85	Nueces	M. L. Rivers No. 1 (Agua Dulce)	7,114	Beaumont	Frio
86	Nueces	Wardner No. 19 (Stratton)	6,433*y*	Beaumont	Frio
87	Nueces	Thompson-No.2 (Riverside)	7,750	Beaumont	Vicksburg
88	Nueces	Walker No. 12 (Richard King)	6,412	Beaumont	Vicksburg
89	Nueces	A. N. Parr No. 1 (Minnie Bock)	3,915	Beaumont	Catahoula
90	Nueces	Howze No. 2 (Minnie Bock)	6,000	Beaumont	Frio
91	Nueces	J. O. Chapman No. 9 (Chapman ranch)	4,550	Beaumont	Catahoula
92	Nueces	Huie No. 2 (So. Clara Driscoll)	6,025	Beaumont	Frio
93	Nueces	Union Central No. 1 (Stratton)	7,192	Beaumont	Frio
94	Nueces	Sands & Eggert No. 1 (Agua Dulce)	7,502	Beaumont	Vicksburg
95	San Patricio	Ivey No. 3 (Midway field)	6,495	Beaumont	Frio
96	San Patricio	Smith No. 1 (Midway field)	6,510	Beaumont	Frio
97	San Patricio	Welder No. 1-C (Odem)	7,213	Beaumont	Frio
98	San Patricio	Lane No. 1 (Odem)	5,460	Beaumont	Frio
99	San Patricio	Lane No. 4 (Odem)	3,548	Beaumont	Catahoula
100	Willacy	Willamar Community No. 1-B (Willamar)	8,728	Alluvium	Frio
101	Willacy	Kent No. 1 (Willamar)	7,970*y*	Alluvium	Frio

the lensing out of sand bodies, occurs in a lateral as well as landward and seaward direction. Sands of the marine beds are usually of large areal distribution and generally retain a relatively uniform thickness throughout their distribution, whereas the sands laid down by land agents are, as a rule, highly lenticular and extend over relatively short distances. Followed downdip, the continental sands are found to grade into marine sands, and the latter to be replaced eventually by marine shales as the seaward direction is continued.

The complexity of Cenozoic sedimentation has brought and will continue to create many problems for the Coastal geologist in his attempts to interpret subsurface conditions. The more successful he is in deciphering the *detailed* geologic history of Cenozoic sedimentation, the

TABLE 2.—(*Continued*)

Important Wildcats and Semiwildcats Drilled in 1941

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
62	Transwestern Oil Co.	154		7/64	1,200	1,200	New 6000-ft. Frio sand
63	Transwestern Oil Co.	160		7/64	1,375	1,190	New 5900-ft. Frio sand
64	La Gloria Oper. Committee	300	80		2,500 (shut-in)		New 6100-ft. Frio sand
65	La Gloria Oper. Committee	200	100				New 5900-ft. Frio sands
66	La Gloria Oper. Committee	150	60				New 6800-ft. Frio sand
67	Magnolia Pet. Co.	167		7/64	1,650	1,425	First crude production in La Gloria Area
68	Magnolia Petr. Co.		80				Extension and new 7100-ft. Vicksburg sand
69	J. A. McCartney	90		¼	575	0–75	New 3700-ft. Frio sand
70	Wilcox Oil & Gas Co.		5	3/16	1,700	1,620	New 4300-ft. Frio sand
71	Smith & Mosser	50	20		1,400 (shut-in)		New 3200-ft. Frio sand
72	Rand Morgan	100		¼			New 3700-ft. Frio sand
73	H. H. Howell	75	10				SE. extension, between Alice & Ben Bolt
74	Chicago Corp.	300	100				Extension west into Jim Wells County
75	Chicago Corp.	200	100				South extension into Kleburg Co.
76	Geo. B. Buescher	175		⅛	1,500	1,220	Opened Petronilla field
77	Osborn & Mid-Continent	12	0.5	¼	600	500	Opened Banquette field
78	Taft Oil Co.	50	3	⅛			1¼ mile south ext. east flank
79	Geo. B. Buescher	76.5		⅛	2,480	1,920	New 6900-ft. Frio sand
80	Osborn & Mid-Continent	500	50	¼	2,400 (shut-in)		New 6900-ft. Frio sand
81	S.E.W. Oil Co.	110		¼	2,350	2,300	1 mile SE. ext. new 7000-ft. Frio sand
82	Seaboard Oil Co.	150		⅛	950	850	Opened Luby Deep field, 7300-ft. Frio sand (Luby)
83	R. H. Hawn	230		⅛	1,745	1,760	Between Agua Dulce and Stratton, new 7000-ft. sand
84	S.E.W. Oil Co.	157		⅛	1,400	1,250	1½ mile east extension, 7100-ft. sand (new?)
85	Wilson & Gulf Plains	172		⅛	1,900	1,300	First crude on west flank
86	Chicago Corp.	230		⅛	1,120	1,160	First crude on west flank
87	Stanolind O. & G. Co.	50	10	⅛	2,450 (working)		New 6900-ft. Frio sand
88	Southern Minerals	13	Gas	⅛			New 6200-ft. Vicksburg sand
89	Windsor Oil Co.	41		7/64	1,150	950	New 3700-ft. Catahoula sand
90	Wellington Oil Co.	50	2.5	5/32	2,000	1,850	New 5500-ft. Frio sand
91	Seaboard Oil Co.	163			(On pump)		New 4200-ft. Catahoula sand
92	Texas Conservative Oil Co.	102		11/64	475	200	1 mile south extension
93	Wilson & Gulf Plains	150	75	⅛			West extension and new 6800-ft. sand
94	Ginther, Warren & Ginther		75	3/32	2,640 (working)		1 mile east extension
95	British-Amer. Prod. Co.	68		⅜	2,050	1,975	New 6000-ft. Frio sand
96	Pan-American Prod. Co.	182		5/32	(Sealed)	900	New 6200-ft. Frio sand
97	Wellington Oil Co.	145		⅛	1,075	625	SW. extension and new 5400-ft. Frio sand
98	Seaboard Oil Co.	221		9/64	(Sealed)	1,000	NW. extension and new 5300-ft. Frio sand
99	Seaboard Oil Co.	5	2.5	¼	1,425	1,350	New 3500-ft. Catahoula sand
100	Pan-American Prod. Co.	91		¼			New 7800-ft. Frio sand
101	Pan-American Prod. Co.	108		¼	(Sealed)	175	1 mile NW. extension and new 7900-ft. Frio sand

	In Proven Fields	Rank Wildcats
Number of wells drilling Dec. 31, 1941	127	37
Number of oil wells completed during 1941	927	11
Number of gas wells completed during 1941	66	4
Number of dry holes completed during 1941	213	230

more successful will be the oil industry in finding those stratigraphic and sedimentary traps that will become increasingly more important as sources of oil in the Coastal area. Certainly the character of sedimentation in this region means, at least, that chances for combinations of shales and sands into sedimentary and stratigraphic petroleum traps are proportional to the complexity of their original relationships and to the complexity of the post-depositional changes in these relationships.

DUVAL COUNTY, LAREDO DISTRICT

New Fields

Agua Prieta Field.—E. R. Thomas Estate's Parr No. 1, Callaghan subdivision, survey 11, one mile east of Muralla field, flowed 52 bbl. of 46° gravity oil daily from perforations at 4711 to 4712 ft. in a Pettus sand at 4708 to 4720 ft. The well had been plugged back to 4726 ft. after drilling to 5025 ft. in the Yegua. Production was through 7/32-in. choke, under 1000 lb. tubing and 1180 lb. casing pressure. Completed 4/13/41.

East Benavides Field.—Hiawatha Oil and Gas Company's Geo. Parr 1-A, San Andres grant, 1½ miles east of Benavides field, produced 169 bbl. of fluid, 80 per cent 43° gravity oil, 20 per cent water daily from perforations at 4915 to 4918 ft. in Jackson (Government Wells) sand at 4915 to 4940 ft. Pressures were 200 lb. on tubing, 1000 lb. on casing. Gas-oil ratio was 155 to 1; total depth, 5040 ft. Completed 7/21/41.

*Coquat-Lopez Field.**—Henderson Coquat's Lopez 1, sec. 455, 7 miles northeast of Bruni, swabbed 100 bbl. of 20.6° gravity oil on Dec. 29, to open this field from Cole sand at 1693 to 1705 ft. (total depth); perforations were made at 1697 to 1703 feet.

Government Wells Yegua.—Sun Oil Company's Wiederkehr 75, sec. 55, one mile northeast of Government Wells field, opened this area with a daily flow of 86 bbl. of 36.2° gravity oil, 3/16-in. choke, from Yegua sand at 2936 to 2940 ft. (total depth). Pressures were 80 lb. on tubing, 585 lb. on casing; gas-oil ratio 180 to 1. Some people consider this area to be an extension and new sand discovery for the Government Wells field. Completed 11/28/41.

Rios Field.—Argo Oil Company's C. Gonzales 1, Carrera grant, 10 miles northwest of Premont, gauged 7,000,000 cu. ft. of gas with 34 bbl. of 51.2° gravity distillate daily to open this field from sand at 6270 to 6308 ft., in Hockleyensis topped at 6146 ft. The well had been drilled to 6308 ft. and was cemented at 6296 ft. after drill stem was stuck there. Perforations were then made at 6270 to 6284 ft. (60 shots); shut-in pressure was 2700 lb. Completed 7/27/41.

New Sands in Existing Fields

Benavides Field.—Hiawatha Oil and Gas Company's Parr 30, a 2000-ft. east extension, produced 5,000,000 cu. ft. of gas and 16 bbl. of 56° gravity distillate daily from a Yegua sand at 5584 to 5594 ft., through perforations at 5588 to 5594 ft. Pressures were 1825 lb. on tubing and 1950 lb. on casing. Total depth was 5995 ft. Completed 3/19/41.

The company's Parr 31 was completed from Yegua sand at 5721 to 5749 ft. Daily flow was 20,000,000 cu. ft. of gas and 100 bbl. of 65° gravity distillate. This sand produces in the Sweden field.

Hoffman Field.—Cox and Hamon's Cuellar 5, C. and M. survey 123, pumped 91 bbl. of 26° gravity oil daily on test from perforations at 3151 to 3152 ft. in a Cockfield sand found at 3142 to 3152 feet.

Labbe Field.—Butler, Carter and Douglas' Labbe 3, I.G.N. survey 2, opened a Frio sand at 1872 to 1902 ft. when it flowed

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* Unofficial name.

750,000 cu. ft. of wet gas daily from perforations at 1896 to 1899 ft., 3/16-in. choke. Tubing pressure was 625 lb.; total depth, 2930 feet.

Sweden Field.—Hiawatha Oil and Gas Company's Herberger 6, sec. 25, ¾ mile south of the field, flowed 220 bbl. of 45° gravity oil daily from upper Jackson sand at 4929 to 4939 ft., 3/16-in. choke; perforations were made at 4932 to 4937 ft. Tubing pressure was 1170 lb.; casing pressure, 1740 lb.; total depth, 4940 feet.

Sejita Field.—Trinity Gas Company's Casey 2, a ¾-mile west extension, Ramirez grant, gauged 35,000,000 cu. ft. of gas and 200 bbl. of 54° gravity distillate daily from perforations at 5770 to 5785 ft. in Hockleyensis sand at 5770 to 5830 ft.; shut-in pressure was 2100 pounds.

The same operator's Yzaguirre 1, a mile east of the field's discovery well, showed for 50,000,000 cu. ft. of gas and 250 bbl. of 54° gravity distillate daily on test through perforations at 5375 to 5395 ft. in Hockleyensis sand; total depth, 5547 feet.

JIM HOGG COUNTY, LAREDO DISTRICT

New Fields

Ramirez Field.—Forest Development Corporation's Ramirez 1, two miles west of the Colorado field, I.G.N. survey 271, flowed 7,000,000 cu. ft. of dry gas daily from perforations at 1998 to 2001 ft., in Mirando sand at 1992 to 2006 ft. Shut-in pressure was 600 lb.; total depth, 3006 ft. in Yegua. Completed 3/31/41.

Chaparosa Field.—Neuhaus and Lucky's Bute 2, El Randado grant, 5 miles southeast of Randado, was brought in as a 20,000,000-cu.-ft. gasser from perforations at 2855 to 2863 ft., in Lower Government Wells sand at 2855 to 2868 ft., ⅛-in. choke. Shut-in pressure was 1100 lb.; total depth, 3465 ft. Completed 5/17/41.

Neuhaus, Adams and Lucky's Gallagher 2 flowed 2,500,000 cu. ft. of gas from Upper Government Wells sand at 2781 to 2792 ft. This daily production was from perforations at 2783 to 2791 ft., under 850 lb. tubing and 975 lb. casing pressures. Total depth was 3071 feet.

Neuhaus Field.—Adams, Neuhaus and Lucky's East 1, about ½ mile south of the Chaparosa discovery well, was completed Dec. 30 for a daily flow of 75 bbl. of oil, ¼-in. choke, from Pettus sand at 3462 to 3471 feet.

Palacios Field.—Bidrich Oil Company's Palacios 1, block 17, sec. 287, about ¾ mile east of Randado field, flowed an estimated 10,000,000 cu. ft. of wet gas daily, ⅛-in. choke, from perforations at 2924 to 2930 ft. in a Yegua sand at 2924 to 2939 ft. Tubing pressure was 985 lb.; casing pressure, 1050 lb.; total depth, 3008 ft. Other sands at 2623 to 2628 ft., 2753 to 2759 ft., and 2851 to 2872 ft. had shows. Completed 9/18/41.

Sun-Jones Field.—Sun Oil Company's Jones 1, Agua Neuva de Abajo grant, 30 miles northeast of Rio Grande City, flowed an estimated 20,000,000 cu. ft. of gas daily, 5/32-in. choke, from perforations at 4230 to 4235 ft. in Jackson sand at 4211 to 4268 ft. Pressures were equalized at 1500 lb. Total depth was 6009 feet. Completed 12/8/41.

LA SALLE COUNTY, LAREDO DISTRICT

New Sands in Existing Fields

Washburn Field.—Quintana Petroleum Company's Washburn 1, survey 67, discovery well for this field, was recompleted on March 3 in Wilcox sand at 5413 to 5430 ft. for a daily pumped production of 65 bbl. of 40.5° gravity oil. Original completion had been made the previous year in Wilcox sand through perforations at 4860 to 4867 ft., but the well made considerable water.

The same company's Washburn 4, sec. 86, 1¼ miles southwest of No. 1, opened a Wilcox sand at 5513 to 5578 ft. A dual sand completion, the well flowed 406 bbl. of 40.3° gravity oil daily, ¼-in. choke,

TABLE 3.—*Deep Wells Drilled during* 1941

County	Location	Company and Well	Depth, Ft.	Formation	Results
LAREDO DISTRICT, WELLS DRILLED TO 6000 FEET AND BELOW					
Duval	Wildcat, 7¾ mi. SE. Realitos, Hinojosa grant	Henderson, Coquat, Garcia No. 1	6,515	Yegua	Dry
Duval	Wildcat, 10 mi. NW. Premont, Carrera grant	Argo Oil Co., Gonzales No. 1	6,308	Hockleyensis gas	
Duval	Wildcat, 3 mi. S. Realitos, Hinojosa grant	H. Coquat, Y. Garcia No. 2	6,008	Yegua	Dry
Duval	Wildcat, share 8, San Francisco grant	H. H. Howell, Escobar No. 1	6,060	Yegua	Dry
Duval	East Benavides field	Hiawatha Oil & Gas, Geo. Parr No. 2-A	6,510	Yegua	Dry
Duval	Wildcat, Sejita area	Trinity Gas. Co., Barerra No. 1	6,085	Yegua	Dry
Duval	Sweden field	Hiawatha Oil & Gas, Miller No. 12	6,015	Yegua	Dry
La Salle	Washburn field	Quintana Petr. Co., Washburn No. 3-A	11,042	Cretaceous	Dry
Starr	LeReforma field	Collins & Co., Guerra No. 2	6,238	Vicksburg	Dry
Starr	Wildcat, share 1, Los Retachez grant	Lewis Prod. Co., Osborn No. 1	6,007	Vicksburg (*y*)	Dry
Starr	Sun field	Sun Oil Co., Speer State No. 6-B	6,001	Jackson	Oil
Starr	La Reforma field	Porter & Pickens, A. Guerra No. 1	6,198	Vicksburg	Oil
Starr	North Sun field, Los Retachez grant	Sun Oil Co., Montalvo No. 1-C	6,607	Jackson	Oil
Webb	Wildcat, 15 mi. NW. Callahan	Magnolia Petr. Co., Hamilton No. 1-A	9,197	Cretaceous	Dry
Webb	Wildcat, 20 mi. E. Laredo	Union Prod. Co., Volpe & Benavides No. 1	7,018	Wilcox	Dry
Webb	Wildcat, sec. 24, 22 mi. NW. Laredo	Magnolia Petr. Co., Santos Tomas No. 1	6,830	Cretaceous	Dry
Jim Hogg	Wildcat, Agua Neuva de Abajo grant	Sun Oil Co., Jones No. 1	6,009	Yegua	Gas
SOUTH CORPUS CHRISTI DISTRICT, WELLS DRILLED TO 7750 FEET AND BELOW					
Brooks	Wildcat, survey 141	Sun Oil Co., Cage No. 1	8,012	Yegua	Dry
Cameron	Wildcat, Skelton survey, 6 mi. SW. Port Isabel	Pure Oil Co., Newberry No. 4	11,266	Frio	Dry
Hidalgo	Wildcat, 1 Mi. S. San Juan	W. R. Davis, Inc., Dawley, Jefferson No. 1	8,508	Vicksburg	Dry
Hidalgo	McAllen field	W. R. Davis, Inc., Arizona & Texas No. 1	8,513	Vicksburg	Distillate and gas
Hidalgo	Wildcat, 5.7 mi. S. Donna La Blanca grant	La Gloria Corp., W. C. Adams No. 1	9,008	Vicksburg	Dry
Jim Wells	La Gloria field	Magnolia Petr. Co., Brethren Church No. 1	8,043	Vicksburg	Dry
Kenedy	Wildcat in Laguna de los Olmos, 7 mi. SE. Riviera	Skelly Oil Co., State Tract 388 No. 1	10,044	Vicksburg	Dry
Kenedy	Wildcat, 8 mi. SW. Mifflin	101 Oil Co. & C. G. Newton, Kenedy No. 2	8,000	Frio	Dry
Nueces	East Flour Bluff field	Humble Oil & Ref. Co., State No. 6-D	8,570	Frio	Dry
Nueces	Clara Driscoll field	Wellington Oil Co. Driscoll No. 2-D	8,055	Vicksburg	Dry
Nueces	Riverside field	Stanolind Oil & Gas Co., Thompson No. 2	7,750	Vicksburg	Distillate and gas
Nueces	Wildcat at Taylor Island Tract 246	Humble Oil & Ref. Co., State Aransas Bay No. 1	9,565	Frio	
Nueces	Chapman field	Seaboard Oil Corp., Chapman No. 10	7,750	Frio	Gas
Nueces	East Flour Bluff field	Humble Oil & Ref. Co., State No. 1-K	8,694	Frio	Oil
Nueces	Stratton field	Hiawatha Oil & Gas Co., Rogers No. 1	8,138	Vicksburg	Oil and gas
Nueces	East Flour Bluff field	Humble Oil & Ref. Co., State No. 7-D	8,641	Frio (Relief well)	
Nueces	Agua Dulce field	Sam E. Wilson, San Antonio Land Bank No. 1-A	8,005	Vicksburg	Dry
Nueces	Saxet field	Southern Minerals-Houston Oil, Lawrence No. 1-A	10,507	Vicksburg	Oil (4716–4724)
Nueces	Wildcat, 5 mi. SW. Clarkwood	Phillips Petr. Co., Mastin No. 1	7,765	Frio	Dry
Nueces	Agua Dulce field	Stanolind Oil & Gas Co., Weinert No. 5	8,510	Vicksburg	Dry
Nueces	East Flour Bluff field	Humble Oil & Ref. Co., State No. 4-E	8,200	Frio	Dry
Willacy	Willamar field	Pan-American Prod. Co., Willamar No. 1-B	8,728	Frio	Oil
Willacy	Wildcat, 1½ mi. NW. La Sal Vieja field	Clark & Cowden, Yturria No. 1	8,505	Frio	Dry
Willacy	Willamar field	Pan American Prod. Co., Estelle Hodge No. 1	7,861	Frio	Oil
Willacy	Willamar field	Pan American Prod. Co., Burgess No. 1	7,983	Frio	Oil
Willacy	Wildcat, 3 mi. NW. La Sal Vieja field	Clark & Cowden, Garcia L. & L. Co. No. 1	8,505	Frio	Dry
Willacy	Willamar field	Pan American Prod. Co., Kent No. 1	7,970 (*y*)	Frio	Oil

TABLE 4.—*Total Number of Wells Drilled in South Texas Fields during* 1941

Field	Distillate or Oil	Gas	Dry	Total
DUVAL COUNTY				
Agua Prieta	1	0	0	1
Benavides	2	1	2	5
East Benavides	1	0	1	2
Bridwell	6	0	1	7
Casa Blanca[1]	19	4	9	32
Cedro Hill	8	0	3	11
Charamousca[2]	18[4]	1	6	25
Chiltipin	1	1	0	2
Colmena	0	0	2	2
Cole Bruni	0	0	1	1
Cole (shallow)[3]	5	0	2	7
Conoco Driscoll	14	0	2	16
Coquat-Lopez	1	0	0	1
Government Wells	3	0	2[4]	5
Hoffman	9	3	8	20
Kohler	0	1	0	1
Kreis	7	0	5	12
Labbe	1	1	0	2
Lopez	0	0	1	1
Lundell	10	4	3	17
Muralla	1	0	0	1
Palangana	0	0	1	1
Peters	0	0	1	1
Piedre Lumbre	7	1	5	13
Rancho Solo	1	0	0	1
Rios	1	0	0	1
Sejita	2	0	1	3
Seven Sisters	2	0	1	3
Southland	0	0	1	1
Sweden	2	0	1	3
Tarancahuas	0	0	3	3
Total	122	17	62	201
JIM HOGG COUNTY				
Chaparosa	0	2	1	3
Colorado	74	1	5	80
South Colorado	0	0	1	1
Henne-Winch-Farris	0	0	1	1
Holbein	9	0	2	11
Kelsey	4	0	1	5
Las Animas	1	1	0	2
Manila	10	2	2	14
Neuhaus	1	0	0	1
Palacios	0	1	0	1
Ramirez	0	1	0	1
Sun-Jones	0	1	0	1
Total	99	9	13	121
MCMULLEN COUNTY				
Calliham	0	0	1	1
South Calliham	0	1	1	2
South Campana	6	1	1	8
Jacob	2	0	0	2
Rhode	0	1	1	2
San Jose	0	0	1	1
Total	8	3	5	16
LA SALLE COUNTY				
Washburn (total for county)	2[5]	0	1	3
STARR COUNTY				
Boyle	3	0	9	12
Kelsey	11	0	5	16
LaReforma	1	0	1	2
Los Olmos	2	0	0	2
Rincon	69	2	11	82
North Rincon	8	1	2	11
Rio Grande City	4	0	6	10
Sullivan City	10	1	0	11
Sun	24	0	6	30
North Sun	1	0	0	1
Young (Charco Blanco)	0	0	1	1
Yturria	4	0	0	4
Yzaguirre	0	0	1	1
Total	137	4	42	183
WEBB COUNTY				
Adami	0	0	1	1
Carolina-Texas	0	0	1[4]	1
Cole West	0	0	2	2
Glen	24	3	1	28
Killam	35	1	1	37
Laurel	0	0	2	2
Volpe	0	0	1	1
Total	59	4	9	72
ZAPATA COUNTY				
Charco Redondo	12	0	0	12
Escobas-Jennings	3	0	7	10
Glen	1	0	1	2
Lopena	0	12[6]	3[4]	15
Total	16	12	11	39
Grand Total, Laredo District	443	49	143	635
BROOKS COUNTY				
Alta Mesa	14	0	0	14
Kelsey	18	1	1	20
La Gloria	5	0	0	5
Palo Blanco	0	0	1	1
Total	37	1	2	40
HIDALGO COUNTY				
McAllen	1	0	0	1
Nichols	11	0	3	14
Sam Fordyce	3	0	0	3
Sullivan City	2	0	0	2
Total	17	0	3	20
JIM WELLS COUNTY				
Alfred[7]	3	1	2	6
Alice	2	0	0	2
East Alice (Tom Graham)	2	1	0	3
Ben Bolt	14	0	2	16
Captain Lucey	1	0	0	1
Clark-Muil	0	0	1	1
Haldeman	1	0	1	2
La Gloria	8	1	2	11
Orange Grove	12	0	3	15
Premont	3	0	2[7]	5
East Premont (Seeligson)	22	0	0	22
Sandia	2	1	1	4
Stratton	1	0	0	1
Wade City	24	0	5	29
Total	95	4	19	118
KENEDY COUNTY				
Baffins Bay (total for county)	0	0	1	1
KLEBURG COUNTY				
Stratton (total for county)	7	0	0	7
NUECES COUNTY				
Agua Dulce	80[4]	5	7	92
North Agua Dulce	2	0	1	3
Banquette	2	0	0	2
Chapman Ranch	2	1	0	3
Clara Driscoll	7	3	2	12
South Clara Driscoll	27	2	6	35
Corpus Christi	1[4]	0	0	1
East Flour Bluff	10	1	4	15
Luby[4]	4[4]	0	1	5
North Luby	1	0	0	1
Minnie Bock	30	0	5	35
Petronilla	2	0	0	2
Richard King	30	0	0	30
Riverside	1	0	0	1
Robston	1	0	2	3
Saxet	2	0	0	2
Shield	7	2	0	9
Stratton	63	1	4[4]	68
Turkey Creek	0	0	2[4]	2
East White Point	6	0	0	6
Total	278	15	34	327
SAN PATRICIO COUNTY				
East Mathis	0	0	1	1
Midway	34	1	6	41
Odem	14	0	1	15
Plymouth	5	0	0	5
East Plymouth	0	0	1	1
White Point	0	0	1	1
East White Point	5	0	1	6
Total	58	1	11	70
WILLACY COUNTY				
Willamar (total for county)	4	0	0	4
Grand Total Corpus Christi District	496	21	70	587
Grand Total South Texas Fields[8]	939	70	213	1222

[1] Includes West Casa Blanca. [2] Includes South Charamousca. [3] Includes East Cole. [4] Includes one deepened well. [5] Includes one recompletion in new zone. [6] Includes five deepened wells. [7] Includes West Alfred (new). [8] Also, two oil wells and one dry hole in Live Oak County portion of Ezzell field; four oil wells, two dry holes in Aransas County portion of Aransas Pass field.

under 525 lb. working pressure and with a gas-oil ratio of 425 to 1, from perforations at 5530 to 5550 ft. Perforations at 4822 to 4832 ft. in Wilcox sand at 4822 to 4841 ft. showed a daily flow of 20,000,000 cu. ft. of gas with distillate, ¼-in. choke, under 1180 lb. tubing and 1350 lb. casing pressure.

McMullen County, Laredo District

New Fields

South Campana Field.—Argo Oil Company's Edrington 1-I, A.B. and M. survey 61, two miles southwest of Campana field, flowed 157 bbl. of 22.8° gravity oil from a Pettus sand at 3012 to 3023 ft. Gas shows were encountered in a Cole sand at 1843 to 1880 ft. and in a Government Wells sand at 2574 to 2588 feet.

The first completion in the Government Wells sand was provided by the company's Edrington 3-I, survey 61. This well flowed 8,000,000 cu. ft. of gas with water from perforations at 2559½ to 2561 ft. in sand at 2554 to 2568 ft., under 900 lb. equalized pressure.

Starr County, Laredo District

New Fields

Yturria Field.—Sun Oil Company's Yturria Land and Livestock No. 1, Porcion 100, sixteen miles east of Rio Grande City, was completed Sept. 22 for a flow of 21 bbl. of 44.2° gravity oil and 1½ bbl. of water daily, $\frac{7}{64}$-in. choke, from perforations at 4232 to 4233 ft. in Frio sand at 4232 to 4248 ft. Pressures were 1200 lb. on tubing, 1550 lb. on casing. Gas-oil ratio was 17,481 to 1; total depth, 4889 feet.

North Sun Field.—Sun Oil Company's Montalvo 1-C, Los Retachez grant, 2 miles northeast of the Sun field, was completed Dec. 23 in a Vicksburg sand at 5376 to 5396 ft. through perforations at 5386 to 5389 ft. Daily flow was 154 bbl. of 46.7° gravity oil, $\frac{7}{64}$-in. choke, under 1485 lb. tubing and 2060 lb. casing pressure. Gas-oil ratio was 1663 to 1; total depth, 6607 feet.

New Sands in Existing Fields

Boyle Field.—Dean and Hendrickson's M. M. Garcia 1, block 215, Porcion 90, a mile northwest extension, flowed 4,000,000 cu. ft. of gas and 35 bbl. of distillate daily to open a new Frio level from perforations at 2850 to 2855 ft. Production was through $\frac{5}{64}$-in. choke under 800 lb. tubing and 1200 lb. casing pressure. Total depth was 3476 feet.

TABLE 5.—*Rank Wildcats (New Field Discoveries) Completed during* 1941

County	Oil	Distillate and Gas	Gas	Dry Holes
LAREDO DISTRICT				
Duval	4	1	0	47
Jim Hogg	1	0	4	30
La Salle	0	0	0	4
McMullen	1	0	0	13
Starr	2	0	0	27
Webb	0	0	0	40
Zapata	0	0	0	11
Total	8	1	4	172
Average, one new field per 14.2 rank wildcats				
SOUTH CORPUS CHRISTI DISTRICT				
Brooks	0	0	0	3
Cameron	0	0	0	1
Hidalgo	0	0	0	4
Jim Wells	2	0	0	20
Kenedy	0	0	0	1
Kleburg	0	0	0	0
Nueces	1	1	0	15
San Patricio	0	0	0	12
Willacy	0	0	0	2
Total	3	1	0	58
Average, one new field per 15.5 rank wildcats				
Grand Total South Texas	11	2	4	230
Average South Texas, one new field per 14.5 rank wildcats				

North Rincon Field.—Sun Oil Company's C. M. Hall 1, survey 99, completed July 11, flowed 1,042,000 cu. ft. of gas with some 52° gravity distillate daily, $\frac{5}{32}$-in. choke, from Vicksburg sand at 4630 to 4670 ft. Perforations were made at 4665 to 4670 ft.; pressures were 1600 lb. on tubing, 1880 lb. on casing; total depth was 5478 feet.

Another Vicksburg sand was opened by the company's Saenz-State 4, Bozan survey 80. This well flowed 134 bbl. of 41.9° gravity oil from sand at 4725 to 4745 ft. (total depth).

TABLE 6.—*New Sand Discoveries in Established Fields, by Counties*

County	Total Field and Extension Wells[1]	New Sand or Oil-in-distillate Sand Discoveries			
		Oil	Distillate and Gas	Gas	Total
LAREDO DISTRICT					
Duval	196	2	4	1	7
Jim Hogg	116	0	0	1	1
La Salle	3	2	0	0	2
McMullen	15	0	0	1	1
Starr	181	3	2	0	5
Webb	72	0	0	0	0
Zapata	39	1	0	2	3
Total	622	8	6	5	19
Average, 1 new sand per 32.7 field or extension wells					
SOUTH CORPUS CHRISTI DISTRICT					
Brooks	40	1	0	0	1
Cameron	0	0	0	0	0
Hidalgo	20	3	1	0	4
Jim Wells	116	8	7	0	15
Kenedy	1	0	0	0	0
Kleburg	7	0	0	0	0
Nueces	325	9	5	0	14
San Patricio	70	4	2	0	5
Willacy	4	2	0	0	2
Total	583	27	15	0	42
Average, 1 new sand per 13.9 field or extension wells					
Grand Total South Texas Fields[1]	1,205	35	21	5	61
Average South Texas, 1 new sand per 19.7 field or extension wells					

[1] Does not include 17 field-discovery wells of 1941.

La Reforma Field.—Porter and Pickens' A. Guerra 1, block 5, share 6, San Jose grant, ½ mile northeast of the field's discovery well, gave added importance to La Reforma field when it flowed 168 bbl. of 42° gravity oil daily, thus providing the first crude to be produced in this distillate-producing area. Production was obtained from perforations at 6152 to 6154 ft. in a new Vicksburg sand at 6140 to 6168 ft. Pressures were 600 lb. on tubing and 800 lb. on casing; total depth was 6198 feet.

Sun Field.—A new Frio sand was opened Oct. 25 by Circle Oil Company's Olivarez 2, survey 241, when it produced 13 bbl. of 47° gravity oil from sand at 4500 to 4565 feet.

ZAPATA COUNTY, LAREDO DISTRICT

New Sands in Existing Fields

Escobas Field.—Dulcy Oil Company's Garcia C-5 produced 5 bbl. of crude daily on pump from a shallow sand at 428 to 448 feet.

TABLE 7.—*Texas Railroad Commission Production Schedule for* 1941

Month	Number of Producing Days	Number of Shut-in Days
January	21	10
February	19	9
March	21	10
April	20	10
May	22	9
June	21	9
July	20	11
August	21	10
September	20	10
October	22	9
November	22	8
December	23	8
Total for 1941	252	113
Total for 1940	295	71
Total for 1939	252	113

Lopena Field.—New deeper sands for this field were discovered by Venture Oil Company's Ramirez 1-B, block 3, share 1, which produced gas under 1000 lb. rock pressure from perforations at 2416 to 2462 ft., and by American-Texas Oil Company's Ramirez 1, which produced gas from perforations at 2500 to 2535 ft. Both levels are in the Queen City formation.

BROOKS COUNTY, SOUTH CORPUS CHRISTI DISTRICT

New Sands in Existing Fields

Kelsey Field.—Humble Oil and Refining Company's McGill Bros. 81 opened a new Frio sand when it flowed 166 bbl. of 45°

gravity oil daily through perforations at 4924 to 4930 ft. from 9⁄64-in. choke. Pressures were 800 lb. on tubing and 1050 lb. on casing; total depth was 4945 ft.

Nichols Field.—Baldridge and King Yturria 1-C, Porcion 43, flowed 110 bbl. of 34.7° gravity oil daily from perforations at 3673 to 3678 ft. in a Frio sand at 3670 to 3678 ft. Pressures were 550 lb. on tubing and 675 lb. on casing; total depth was 3960 ft. Completed 3/14/41.

The same company's Yturria D-4 topped another lower Frio sand at 3904 ft. and on May 9 flowed 116.6 bbl. of 37.6° gravity oil through ⅛-in. choke, under 400 lb. tubing and 650 lb. casing pressure from perforations at 3904 to 3912 ft. Total depth was 3927 feet.

The company's Yturria B-1, completed Feb. 13, flowed 88 bbl. of 37.7° gravity oil daily from a Frio sand at 3869 to 3875 ft.; total depth, 3955 feet.

McAllen Field.—Davis Inc.'s Arizona and Texas Citrus 1, lot 1, block 8, a 7250-ft. southeast extension, was completed on Aug. 24 from Frio sand at 7520 to 7550 ft. for a daily flow of 21,500,000 cu. ft. of gas and 100 bbl. of 52.4° gravity distillate, ⅝-in. choke. Pressures were 3000 lb. on tubing, 3030 lb. on casing. Total depth was 8513 feet.

JIM WELLS COUNTY, SOUTH CORPUS CHRISTI DISTRICT

New Fields

Haldeman Field.—Magnolia Petroleum Company's Seeligson Unit 4, well 1, sec. 68 opened the Haldeman field, producing from a Frio sand at 5019 to 5040 ft., 8000 ft. southeast from the Premont pool. Completion was attempted first with a total depth of 5038 ft., but perforations at 5024 to 5030 ft. showed an extremely high gas volume, which was cut off only after three squeeze jobs. The sand was then penetrated to 5040 ft., and final completion on Apr. 25 resulted in a flow of 106 bbl. of 40.3° oil daily, ⅛-in. choke. Pressures were 700 lb. on tubing and 1725 lb. on casing. Gas-oil ratio was 450 to 1.

West Alfred (New) Field.—Howeth and Wilcox's Adams 1, R. Adams survey, 1½ miles west of West Alfred field, flowed 147 bbl. of 47.4° gravity oil from perforations at 4195 to 4200 ft. in a Frio sand, at 4194 to 4206 ft. Some people consider this a new producing area, but officially it is listed, together with West Alfred, as part of the Alfred field, discovered in February 1938. Before completion was made in this sand, a lower sand was tested through perforations at 4312 to 4322 ft. and showed oil, mud, and water. Completion was on Aug. 4; production was under 520 lb. tubing and 1500 lb. casing pressure. Gas-oil ratio was 665 to 1; total depth, 5185 feet.

Wilcox Oil and Gas Company's Adams 2 opened the lower sand on Dec. 12 when it flowed 5,000,000 cu. ft. of gas with a spray of 48.5° gravity oil from perforations at 4304 to 4308 ft. in Frio sand at 4304 to 4313 ft. Tubing pressure was 1620 lb.; casing pressure, 1700 lb.; total depth, 4390 feet.

New Sands in Existing Fields

East Premont (Seeligson) Field.—Magnolia Petroleum Company's Seeligson 15, Ramirez grant, flowed 167.5 bbl. of 39.9° gravity oil, 5⁄32-in. choke, from perforations at 5897 to 5899 ft. in a new Frio horizon at 5885 to 5900 ft. Total depth was 5903 ft. Pressures were 900 lb. on tubing and 1000 lb. on casing. Gas-oil ratio was 669 to 1. Completed 4/17/41.

The same company's Seeligson 16 extended the field ¼ mile north and opened production from a Frio sand through perforations at 6446 to 6448 ft. on July 1. The well gauged 3,700,000 cu. ft. of gas and 40 bbl. of 55° gravity distillate. Total depth was 6626 feet.

Seeligson 17, ¼ mile northwest outpost, flowed 125 bbl. of 40° gravity oil, ⅛-in.

choke, from 12 perforations at 5555 to 5557 ft. in another Frio sand. Pressure was 570 lb. on tubing; 1000 lb. on casing; gas-oil ratio, 465 to 1; total depth 6856 ft. Completed 7/24/41.

Sun Oil Company's Canales 1, survey 182, extended the field one mile west and opened a new Frio horizon at 5198 to 5210 ft. on July 13, when it gauged 173 bbl. of 39.9° gravity oil, ¼-in. choke, through 20 perforations at 5202 to 5207 ft. Total depth was 5210 ft.; pressure on tubing, 220 lb.; on casing, 1175 lb.; gas-oil ratio, 300 to 1.

Transwestern Oil Company's Dunlap 2, in the southeast portion of the field, flowed 154 bbl. of 39.9° gravity oil, 7⁄64-in. choke, after being perforated at 6090 to 6094 ft. in a Frio sand topped at 6080 ft. after plugging back from 6796 ft. Pressure was 1200 lb. on both tubing and casing; gas-oil ratio, 974 to 1.

Transwestern's Dunlap 3, a ¼-mile south extension, flowed 160 bbl. of oil daily through 7⁄64-in. choke, from Frio sand topped at 5950 ft. through perforations at 5983 to 5988 ft. Pressures were 1190 lb. on tubing, 1375 lb. on casing. Gas-oil ratio was 368 to 1. The 6100-ft. sand was found low and perforations at 6132 to 6134 ft. had showed salt water. Total depth was 6276 feet.

Wade City Field.—Smith and Mosser's B. H. Mueller 1 flowed 20,000,000 cu. ft. of gas with a spray of 50° gravity distillate from perforations in a Frio sand at 3283 to 3302 ft. Shut-in pressure was 1400 lb.; total depth, 5100 feet.

La Gloria Field.—A new horizon was opened on Apr. 15 by the La Gloria Operators Committee's Scott 1, lot 2, block 9, La Gloria townsite; this well was completed in two Frio horizons—a new sand at 6180 to 6205 ft., the other at 6037 to 6055 ft. Daily flow was gauged at 80,000,000 cu. ft. of gas and 300 bbl. of 55° gravity distillate daily.

The same operators' N. Lafferty 1, a March completion, gauged 100,000,000 cu. feet of gas and 200 bbl. of 55° gravity distillate daily production when completed through perforations at 5912 to 5927, 5980 to 5990, 6097 to 6105, and 6120 to 6132 ft. All levels are in the Frio. Total depth was 6902 feet.

La Gloria 14, lot 7, block 9, completed on July 7, flowed 60,000,000 cu. ft. of gas with 150 bbl. of 55° gravity distillate daily from Frio sand at 6790 to 6820 ft. Total depth was 6900 feet.

Magnolia Petroleum Company's D. O. Maun 2, on the west flank of the field, discovered the first commercial crude production for the La Gloria area on Oct. 6, when it was completed from perforations at 6670 to 6700 ft. for 167 bbl. of 39.5° gravity oil, 7⁄64-in. choke, under 1425 lb. tubing and 1650 lb. casing pressure, gas-oil ratio being 1420 to 1. Perforations at 6041 to 6060 and 6100 to 6112 ft. showed only gas and distillate. This well was drilled as the La Gloria Operators Committee's Unit 18, but since crude-oil rights were retained by the Magnolia, it was taken over by the latter company. Total depth was 6901 ft. This indicates important flank development.

Magnolia's Conkle 1, lot 8, block 6, was completed Oct. 3 in Vicksburg sand at 7138 to 7168 ft., for a production of 80,000,000 cu. ft. of gas with 55° gravity distillate.

Premont Field.—J. A. McCartney's Isham 1, sec. 78, opened a new Frio sand for this field when it produced 90 bbl. of 23° gravity oil (4 per cent water) from perforations at 3706 to 3716 ft. in sand at 3706 to 3722 ft. Production was under 0–75 lb. tubing pressure and 575 lb. casing pressure, through open tubing. Total depth was 3936 ft. Completed 7/6/41.

Henshaw Field.—Rand Morgan's Fee 1-H, a mile south extension, flowed 100 bbl. of 53° gravity oil, ¼-in. choke, from perforations at 3780 to 3792 ft. in a new Frio sand. Total depth was 5800 feet.

Nueces County, South Corpus Christi District

New Fields

Banquette Field.—Osborn and Mid-Continent Petroleum Company's Burow 1, Lot 69, Pauls subdivision, 2 miles northeast from Banquette, was completed Apr. 22 from perforations at 6712 to 6714 ft., in Frio sand at 6705 to 6714 ft. An erratic flow of gas and distillate, which began at the daily rate of 176 bbl. of 60.5° gravity distillate (3-hr. gauge) under 1635 lb. tubing and 2200 lb. casing pressures, 7/64-in. choke, later became stabilized at 12 bbl. of 58.6° gravity distillate and 500,000 cu. ft. of gas daily, ¼-in. choke, under 500 lb. tubing and 600 lb. casing pressures. Total depth was 7512 feet.

The same operators' Grove 1, lot 68, 3100 ft. south of the discovery well, flowed an estimated 50,000,000 cu. ft. of gas and 500 bbl. of 56° gravity distillate daily from perforations at 6978 to 6983 ft. in Frio sand. Shut-in pressure was 2400 lb.; total depth, 7538 ft. Completed 12/8/41.

Petronilla Field.—Geo. B. Buescher's J. T. Gillette 1, tract 6, C.D.C. survey, 2 miles northeast of Luby field, was completed Sept. 21 in Frio sand, at 7308 to 7315 ft., for a flow of 175 bbl. of 40° gravity oil, ⅛-in. choke, from perforations at 7308 to 7312 ft. Pressures were 1220 lb. on tubing, 1500 lb. on casing. Other Frio sands at 5475 to 5497 and 5850 to 5890 ft. showed distillate, while other sands at 6475 to 6497, 6952 to 6968, and 7052 to 7084 ft. showed oil. Total depth was 7315 feet.

The 6900-ft. sand was opened Oct. 28 by the same operators' J. R. Knight 1, tract 5, north offset to the discovery. After coring, perforations were made at 6959 to 6964 ft., and the well flowed 76.5 bbl. of 44° gravity oil, ⅛-in. choke, under 1920 lb. tubing and 2480 lb. casing pressures. Gas-oil ratio 4880 to 1; total depth, 7365 feet.

New Sands in Existing Fields

Luby Field.—Seaboard Oil Company's Luby 9, originally completed at 5068 ft. was deepened to 7313 ft. in basal Frio and flowed 150 bbl. of 37.2° gravity oil daily, ⅛-in. choke, from perforations at 7310 to 7312 ft. in a sand topped at 7308 ft. Pressures were 850 lb. on tubing and 950 lb. on casing. Gas-oil ratio was 1210 to 1. This new deep level is considered a separate field for proration purposes; it has been named "Luby Deep" field.

Agua Dulce Field.—S.E.W. Oil Corporation's Pfluger 2, sec. 186, a mile southeast of production, produced 15,000,000 cu. ft. of gas and 110 bbl. of 56° gravity brown distillate, ¼-in. choke, from perforations at 6997 to 7012 ft. in Frio sand cored at 6997 to 7018 ft. Pressures were 2300 lb. on tubing, 2350 lb. on casing. Total depth was 7143 feet.

The same company's Pfluger 1-B, ½ mile downdip from No. 2, flowed 157 bbl. of 40.2° gravity crude, ⅛-in. choke, from perforations at 7100 to 7110 ft. in Frio sand at 7100 to 7123 ft.; this may be the same sand producing in No. 2. Pressures were 1250 lb. on tubing, 1400 lb. on casing. Gas-oil ratio was 670 to 1; total depth, 7161 feet.

R. H. Hawn's Bush-Wofford 1, between Agua Dulce and Stratton fields, sec. 205, was perforated at 7001 to 7005½ ft. in Frio sand at 7001 to 7016 ft. and flowed 230 bbl. of 38.6° gravity oil daily, ⅛-in. choke, under 1760 lb. tubing and 1745 casing pressures. Gas-oil ratio was 743 to 1; total depth, 7210 ft. Although this and the sand in the Pfluger No. 2 well are at approximately the same depth, the latter is considered lower stratigraphically.

Sam E. Wilson, Jr., and Gulf Plains Corporation's M. L. Rivers 1, sec. 18, 1½ miles west of production, extended the field and proved the first crude production on the west flank of Agua Dulce. The well flowed 172 bbl. of 42.8° gravity oil, ⅛-in. choke, from perforations at 5830 to 5850 ft.

in Frio sand. Pressures were 1300 lb. on tubing and 1900 on casing. Gas-oil ratio was 840 to 1; total depth, 7114 feet.

Stratton Field.—Chicago Corporations' Wardner 19 opened crude production on the west flank of Stratton field when it flowed 230 bbl. of 40.3° gravity oil, ⅛-in. choke, on completion from a regular Frio sand through perforations at 6423 to 6433 ft. Pressures were 1160 lb. on tubing, 1120 lb. on casing. Gas-oil ratio was 650 to 1.

Sam E. Wilson and Gulf Plains Corporation's Union Central 1, sec. 2, a west extension, produced gas and distillate from perforations at 6658 to 6681, 6700 to 6726, 6734 to 6770, and 6804 to 6823 ft. in Frio sands. Total depth was 7192 ft. The lowest perforations are in a new zone.

Other wells probably have uncovered sand lenses that are not listed because of the indefiniteness of their classification as new sands, owing to the complexity of sand conditions in the major Agua Dulce-Stratton area.

Riverside Field.—Stanolind Oil and Gas Company's Thompson 2, lot 24, Wintergarden subdivision, flowed 10,000,000 cu. ft. of gas and 50 bbl. of 55° gravity distillate under 2450 lb. working pressure, from perforations at 6970 to 6975 ft., in a Frio sand topped at 6970 ft. This sand is about 2000 ft. below the field's discovery Frio sand. Total depth was 7750 feet.

Richard King Field.—Southern Mineral's Walker 12, sec. 33, flowed much gas along with 13 bbl. of 56° gravity distillate, to open a Vicksburg sand at 6230 to 6235 ft. Total depth was 6412 feet.

Minnie Bock Field.—Windsor Oil Co. opened a new Catahoula sand in the eastern part of the Minnie Bock field when its A. N. Parr 1, sec. 37, Paul's subdivision, flowed 41 bbl. of 24.5° gravity crude daily, 7⁄64-in. choke, from sand at 3698 to 3712 ft. Pressures were 950 lb. on tubing and 1150 lb. on casing. Gas-oil ratio was 1400 to 1. The well had been carried to 3915 ft. after salt water had been found in the regular 3800-ft. Catahoula sand. Completed 5/14/41.

A Frio sand, deepest in the field, was opened July 25 by Wellington Oil Company's Howze 2, sec. 56, which flowed 2,500,000 cu. ft. of gas and 50 bbl. of 55° gravity distillate daily, 5⁄32-in. choke, from perforations at 5510 to 5518 ft. Pressures were 1850 lb. on tubing, 2000 lb. on casing. Total depth was 6000 feet.

Chapman Ranch Field.—Seaboard Oil Company's J. O. Chapman 9, sec. 45, was completed on June 23, for a production of 163 bbl. of 27.9° gravity oil on pump from a Catahoula sand at 4269 to 4279 ft. Perforations were made at 4270 to 4274 ft. Total depth was 4550 feet.

The same company's J. O. Chapman 10, sec. 45, flowed an estimated 30,000,000 cu. ft. of gas daily from perforations at 4244 to 4249 ft. from the same Catahoula sand. Total depth was 7750 feet.

SAN PATRICIO COUNTY, SOUTH CORPUS CHRISTI DISTRICT

New Sands in Existing Fields

Midway Field.—British-American Oil Producing Company's Ivey 3, north end of the field, flowed 68 bbl. of 46.5° gravity oil through perforations at 6050 to 6051 ft. in a new Frio sand topped at 6048 ft. Pressures were 1975 lb. on tubing, 2050 lb. on casing. Gas-oil ratio was 2600 to 1; total depth, 6495 feet.

Pan-American Production Company's Smith 1, sec. 72, flowed 182 bbl. of 42.3° gravity oil, 5⁄32-in. choke, 900 lb. tubing pressure, to open a new Frio sand at 6255 to 6280 ft. on Sept. 15. Gas-oil ratio was 1280 to 1; total depth, 6510 feet.

Odem Field.—Wellington Oil Company's Welder 1-C, Hart and Sons survey, one mile southwest of the field, showed a daily flow of 145 bbl. of 35.6° gravity oil, ⅛-in. choke, from a new Frio sand at 5426 to 5444 ft., through perforations at

5430 to 5434 ft. Tubing pressure was 625 lb.; casing pressure, 1075 lb.; gas-oil ratio, 503 to 1; total depth, 7213 ft. Previous perforations at 6715 to 6720 ft., another new level, showed 36 bbl. of 57° gravity distillate and 2,000,000 cu. ft. of gas on a 24-hr. gauge. Completed 6/27/41.

Seaboard Oil Company's Lane 1 provided another new Frio sand on Aug. 25, when it flowed 221 bbl. of 36° gravity oil daily, 9/64-in. choke, from perforations at 5317 to 5327 ft. in sand at 5309 to 5330 ft. Tubing pressure was 1000 lb.; gas-oil ratio, 840 to 1; total depth, 5460 ft. This well opened the area on the upthrow side of a fault on the west side of the field.

The same company's Lane 4 produced 2,500,000 cu. ft. of gas and 5 bbl. of 56° gravity distillate daily, 1/4-in. choke, from perforations at 3541 to 3546 ft., in a Catahoula sand at 3538 to 3548 ft. Pressures were 1350 lb. on tubing; 1425 lb. on casing. Total depth was 3548 ft. Completed 11/11/41.

WILLACY COUNTY, SOUTH CORPUS CHRISTI DISTRICT

New Sands in Existing Fields

Willamar Field.—Pan-American Production Company's Willamar Community 1-B, a south offset to the field's discovery well, was completed in a new Frio sand, topped at 7847 ft., for a daily flow of 91 bbl. of 30° gravity oil, 1/4-in. choke, from perforations at 7855 to 7880 ft. Total depth was 8728 feet.

The same company's Kent 1, share 13, a mile northwest extension, flowed 108 bbl. of 30.4° gravity oil, 1/4-in. choke, 175 lb. tubing pressure, from Frio sand at 7925 to 7970 ft., where 225 perforations were made. Perforations in sands at 7830 to 7843, 7845 to 7885 and 7905 to 7915 had shown high gas-oil ratios.

Developments in West Texas during 1941

By Taylor Cole* and William T. Schneider†

Drilling in West Texas during 1941 was more active than in any year since 1937, a total of 2325 wells having been drilled. Pre-Permian exploration was the greatest in the history of the area; 106 wells tested pre-Permian formations during the year. Wildcatting reached the peak since 1937, with 135 wildcats, of which 20 per cent were producers. The wells were drilled to a greater average depth than in any previous year. Slim-hole drilling was the common practice, using drilling equipment that is largely portable. Because of deeper drilling, more attention was paid to mud fluids, especially the use of materials to reduce water filtration.

There has been slight improvement in the protection of the pay horizons while drilling by the use of reverse circulation, and drilling-in with oil as well as low water-filtration muds. The practice of setting and cementing the oil strings through the producing formation and perforating opposite the pay zones has increased in the fields producing from sands. It is doubtful whether this practice is of unusual value in dolomitic limestone fields.

There have been few if any technological improvements in obtaining necessary information on the pay sections penetrated, by coring, core analyses, better sampling, and more detailed drilling time. However, more operators are beginning to realize the necessity of good samples. For a proper study of the reservoirs in West Texas, it is essential that better samples be obtained, that more core analyses be run, and that better methods of obtaining drilling time be initiated.

It should be noted that increased drilling speeds and slim-hole drilling have tended to reduce coring and core recovery and have not aided in obtaining good subsurface samples. In fact, fast drilling speeds and slim-hole drilling have reduced the cost of drilling operations, but with the sacrifice of much needed subsurface information.

Larger quantities of slower-reacting acid are being used per well. There has been improvement in shooting, in that a greater number of quarts per foot have been used and an attempt has been made to concentrate the shots opposite the pay zone.

The use of mud logging to determine the characteristics of the pay section increased considerably over the year 1940.

There has been a slight increase in obtaining reservoir information in the new fields, such as bottom-hole sampling, bottom-hole pressures, and records of gas, oil, and water withdrawals. However, there is great need for more data on these subjects, particularly accurate information regarding gas and water volumes.

There are three repressuring projects and a fourth is nearly ready for operation in the Kermit field. There is one repressuring project in the Payton field and one in the North Ward field. So far, the gas-injection projects have not shown very impressive results. As yet, there are no water-flooding projects or water-disposal projects in West Texas.

Not including gathering lines within the fields, 222 miles of feeder pipe lines were

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TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	*County*, Field	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1941	During 1941
1	*Andrews:* Deep Rock, Fuhrman, Walker	1931	3,000	0	3,724,841	536,404
2	Emma	1937	1,420	0	931,469	358,550
3	Means	1934	7,600	0	5,364,197	1,324,967
4	Parker	1934	160	0	79,102	9,916
5	West Andrews	1940	640	y	22,832	18,279
6	*Cochran:* Dean	1937	360	0	75,158	13,031
7	Rhodes	1941	40	0	1,884	1,884
8	*Crane:* Dune	1938	2,200	0	451,072	170,241
9	Sand Hills (Permian)	1930	7,000	0	3,193,181	984,660
10	Sand Hills (Ordovician)	1936	1,040	0	579,542	207,227
11	Ella Waddell	1940	640	0	24,648	18,771
12	Waddell-Edwards	1935	2,120	0	[1]	517,818
13	*Crane-Upton:* McElroy	1926	15,500	0	122,120,894	4,788,443
14	*Crockett:* Bean	1941	40	0	3,815	3,815
15	Clara Couch	1941	640	0	986	986
16	Crockett	1938	1,020	0	271,412	79,098
17	Hoover	1938	160	0	y	1,839
18	Live Oak	1940	160	0	1,612	1,612
19	Noelke	1940	1,000	1,000	107,517	95,027
20	Olson	1940	160	0	4,637	4,637
21	Simpson	1938	320	0	x	1,793
22	Todd Deep	1940	1,000	0	132,977	104,436
23	World-Powell	1926	2,380	0	7,537,447	510,749
24	Wyatt	1940	40	0	10,194	4,552
25	*Dawson:* Welch	1941	160	0	195	195
26	*Ector:* Douro	1940	40	0	Field abandoned	586
27	Foster-Johnson-South Cowden	1930	24,560	0	20,619,486	9,864,157
28	Goldsmith	1934	30,000	x	32,730,198	8,190,191
29	North Goldsmith	1936	1,000	x	67,921	49,759
30	Harper	1933	4,500	0	7,287,688	1,039,181
31	North Cowden	1930	18,600	0	20,927,631	4,897,851
32	North Cowden Deep	1939	200	0	90,642	42,015
33	Penwell	1930	6,200	x	[2] 30,605,772	1,464,455
34	*Ector Crane:* Jordan	1937	5,620	x	[1]	1,488,033
35	*Gaines:* Cedar Lake	1939	3,600	0	256,142	202,960
36	Seminole	1937	11,000	0	3,917,536	2,603,667
37	Wasson Deep	1940	40	0	21,022	19,173
38	Wasson "72"	1941	40	0	1,077	1,077
39	*Gaines-Yoakum:* Wasson	1936	58,000	y	33,050,363	13,012,444
40	*Garza:* Garza[3]	1935	80	0	130,533	11,952
41	*Glasscock-Howard:* Chalk-Roberts	1927	21,700	0	100,018,767	4,727,414
42	1,400-foot pay	1927	1,700	0	[4]	
43	1,800-foot pay	1926	4,000	0	[4]	
44	2,200-foot pay	1929	8,000	0	[4]	
45	2,500-foot pay	1928	2,000	0	[4]	
46	3,000-foot pay	1928	6,000	0	[4]	
47	*Hockley-Cochran-Terry:* Slaughter	1937	57,000	0	6,960,645	4,850,451
48	*Howard:* Iatan-Denman	1926	7,000	0	15,009,142	1,451,603
49	Moore	1938	640	0	70,871	14,871
50	Snyder	1937	1,000	0	2,025,835	355,167
51	*Irion:* Irion	1929	340	0	152,718	3,676
52	*Kimble:* Boldt	1938	20	0	1,552	689
53	*Loving:* Mason	1936	350	0	442,579	62,536
54	Wheat	1925	4,060	0	8,573,858	397,484
55	*Lubbuck:* Lubbock	1941	40	0	1,195	1,195
56	*Mitchell:* Westbrook	1921	4,060	0	11,030,580	239,447
57	*Pecos:* Abell	1940	3,320	0	211,227	205,577
58	2,300-foot pay	1941	80	0	[4]	
59	3,300-foot pay	1941	80	0	[4]	

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[b] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Total production included in Penwell total.

[2] Includes Jordan and Waddell accumulative production.

[3] Includes production figures of old abandoned Justiceburg-Emerald pool.

[4] Production of various pays included in field total.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]
				During 1941		End of 1941			Number of Wells				
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941	
1	x	1,500	65	0	0	1	64	0	40	24	1,800	1,350	
2	x	y	50	14	0	0	50	0	10	40	1,500	y	
3	6,210	990	124	5	1	0	122	1	59	63	1,900	1,480	
4	x	y	2	0	0	0	2	0	0	2	y	y	
5	y	y	7	4	0	1	6	0	2	5	y	y	
6	x	y	3	0	1	0	2	0	1	1	x	y	
7	x	y	1	1	0	0	1	0	0	1	y	y	
8	x	y	29	4	0	0	27	0	12	15	740	1,050	
9	4,279	2,260	128	41	2	1	125	0	111	14	2,125	1,467	
10	y	y	26	17	0	0	26	0	23	3	2,760	2,750	
11	0	0	4	2	0	0	4	0	1	3	1,500	y	
12	x	y	80	16	0	0	80	0	69	11	y	y	
13	x	y	y	y	y	0	582	0	154	428	x	200	
14	4.2	4.2	1	1	0	0	1	0	0	1	x	y	
15	x	y	2	2	0	0	2	0	1	1	y	y	
16	x	y	36	8	0	0	36	0	8	28	x	y	
17	x	x	2	1	0	0	2	0	0	2	x	y	
18	y	y	1	0	0	0	1	0	0	1	y	y	
19	y	y	33	23	0	0	25	8	24	1	y	y	
20	y	y	1	0	0	0	1	0	0	1	y	y	
21	x	y	1	0	0	0	1	0	0	1	x	y	
22	x	y	13	6	0	0	13	0	13	0	2,625	2,600	
23	x	x	87	16	1	2	63	0	0	63	x	y	
24	x	y	2	0	1	0	1	0	1	0	x	y	
25	0.1	0.1	1	1	0	0	1	0	0	1	y	y	
26	0	0	1	1	2	2	0	0	0	0	1,010	x	
27	85,041	32,000	1,183	542	0	4	1,179	0	840	339	1,740	1,250	
28	69,110	16,424	964	63	0	0	957	7	919	38	1,675	1,360	
29	959	218	11	5	0	0	10	1	8	2	x	y	
30	x	x	184	2	0	1	183	0	22	162	1,450	500	
31	x	y	506	95	0	0	506	0	447	59	1,740	1,165	
32	x	y	5	0	0	0	5	0	4	1	1,300	y	
33	y	y	175	3	0	0	175	0	104	77	1,375y	715	
34	y	y	225	27	0	0	221	0	185	36	1,285	1,055	
35	44	31.3	34	23	1	1	33	0	1	32	1,876	1,650	
36	3,678	2,145	283	119	0	0	283	0	280	3	2,000	1,930	
37	x	y	1	0	0	0	1	0	1	0	y	y	
38	x	y	1	1	0	0	1	0	1	0	y	y	
39	y	y	1,312	264	0	0	1,312	0	1,253	58	1,800	1,168	
40	x	x	5	0	0	0	5	0	0	5	x	x	
41	x	y	999	4	2	14	820	0	0	820	x	x	
42	y	y	107	0	1	0	106	0	0	106	x	x	
43	y	y	268	0	1	14	205	0	0	205	x	x	
44	x	y	125	0	0	0	78	0	0	78	x	x	
45	x	x	285	2	1	2	234	0	0	234	x	x	
46	x	y	214	2	1	0	197	0	0	197	x	x	
47	x	y	849	681	0	0	849	0	822	27	1,725	1,590	
48	x	x	293	16	0	1	290	0	2	289	x	x	
49	x	y	6	0	0	0	6	0	0	6	x	y	
50	x	y	97	6	0	0	97	0	0	97	x	y	
51	x	x	17	0	0	3	6	0	0	6	x	x	
52	y	y	1	0	0	0	1	0	0	1	x	x	
53	x	y	10	0	0	0	10	0	5	5	x	y	
54	x	y	90	0	0	1	89	0	39	49	1,650	y	
55	x	x	1	1	0	0	1	0	0	1	y	y	
56	x	y	139	0	0	7	88	0	0	88	1,000	50y	
57	201.9	201.9	55	54	0	0	52	3	50	2	2,304	2,402	
58	[4]	y	2	2	0	0	2	0	2	0	x	y	
59	[4]	y	2	2	0	0	2	0	2	0	x	y	

TABLE 1.—(*Continued*)

Line Number	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
							Depth, Avg. Ft.					
	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	28	4.7	San Andres	Per	D	Por	4,350	4,500	25	A	San Andres	4,765
2	34.6	y	San Andres	Per	D	Por	4,190	4,275	25	A	San Andres	4,500
3	29	0.6	San Andres	Per	D	Por	4,475	4,535	25	A	San Andres	5,227
4	29.5	y	San Andres	Per	D	Por	4,627	4,790	5	MC	San Andres	4,814
5	36	y	San Andres	Per	D	Por	4,300	4,400	25	A	Ellenburger	8,368
6	30	y	San Andres	Per	D	Por	4,900	5,010	y	y	Clear Fork	6,621
7	31	y	San Andres	Per	D	Por	5,050	5,111	y	x	San Andres	5,150
8	36	y	Grayburg	Per	D	Por	3,150	3,270	45	A	San Andres	3,795
9	35	y	Wichita	Per	D	Por	4,250	4,630	40	A	Pre-Cambrian	7,158
10	37.5–44.7	0	Simpson and Ellenburger	Ord	S & D	Por & Cav	5,550 5,900	5,600 6,000	20	AF	Pre-Cambrian	7,158
11	35	y	Grayburg	Per	D	Por	3,250	3,400	20	A	San Andres	3,734
12	34.4	y	San Andres	Per	D	Por	3,500	3,520	20	A	San Andres	3,859
13	30	2.4	Grayburg	Per	D	Por	2,800	3,000	40	A	Ellenburger	12,786
14	26	y	San Andres	Per	D	Por	1,451	1,456	5	x	Ellenburger	7,010
15	26	y	San Andres	Per	D	Por	1,882	2,003	20	A	San Andres	2,166
16	31	1.7	Grayburg	Per	DS	Por	1,330	1,450	7	A	San Andres	1,635
17	26.8	y	Queen	Per	S	Por	1,425	1,450	10	N	San Andres	2,173
18	30	y	San Andres	Per	D	Por	2,012	2,145	10	x	San Andres	2,150
19	32	y	Seven Rivers	Per	S	Por	1,100	1,115	y	MC	San Andres	2,039
20	25	y	San Andres	Per	D	Por	2,202	2,250	15	A	San Andres	2,371
21	y	y	Grayburg	Per	D	Por	1,885	1,970	10	N	Grayburg	1,970
22	41.6	0	Crinoidal (Strawn)	Pen	L	Por	5,727	5,802	75	A	Ellenburger	7,010
23	29	0.6	Grayburg	Per	D	Por	2,415	2,555	13	A	San Andres	3,695
24	23	y	San Andres	Per	D	Por	1,500	1,520	5	A	Ellenburger	7,010
25	33	y	San Andres	Per	D	Por	4,918	4,986	y	A	San Andres	4,986
26	29.5	y	San Andres	Per	D	Por	4,315	4,362	20	A	San Andres	4,410
27	34	1.4	Grayburg-San Andres	Per	D & S	Por	4,000	4,350	20	A	Clear Fork	5,500
28	36	1.9	San Andres	Per	DL	Por	4,180	4,250	70	A	San Andres	4,557
29	35	y	San Andres	Per	DL	Por	4,249	4,465	25	A	Wichita	6,422
30	37	1.1	San Andres	Per	D	Por	4,000	4,200	20	MC	San Andres	4,518
31	34	y	Grayburg	Per	DS	Por	4,000	4,200	20	MC	Clear Fork (?)	5,200
32	34	1	Clear Fork (?)	Per	L	Por	5,100	5,150	5	A	Clear Fork (?)	5,200
33	35	2.6	San Andres	Per	D	Por	3,550	3,675	30	A	San Andres	4,002
34	36	2.1	San Andres	Per	D	Por	3,500	3,650	20	A	San Andres	4,038
35	33	2.1	San Andres	Per	D	Por	4,650	4,900	25	A	San Andres	5,885
36	34	y	San Andres	Per	D	Por	5,000	5,370	90	A	San Andres	5,477
37	34	y	Clear Fork	Per	D	Por	6,210	6,881	y	x	y	11,108
38	34	y	y	Per	D	Por	7,055	7,433	y	y	y	11,108
39	34	1.8	San Andres	Per	D	Por	4,900	5,200	y	AM	y	11,108
40	y	y	San Andres	Per	DL	Por	2,800	2,920	20	A	San Andres	2,940
41	y	y	Data on producing formation and deepest zone tested included separately									
42	32	1	Yates	Per	S	Por	1,280	1,400	20	A	Ellenburger	10,906
43	32	0.8	Seven Rivers (?)	Per	S	20	1,650	1,900	20	A	Ellenburger	10,906
44	30	1.6	Grayburg (?)	Per	DL	Por	2,150	2,300	30	A	Ellenburger	10,906
45	30	0.9	San Andres	Per	DL	Por	2,400	2,500	30	A	Ellenburger	10,906
46	27	3.4	San Angelo-Clear Fork	Per	DL & S	Por	2,900	3.000	20	A	Ellenburger	10,906
47	32	1.9	San Andres	Per	D	Por	4,950	5,050	y	MC	Clear Fork	7,000
48	27	1.9	Clear Fork	Per	D	Por	2,450	2,800	50	A	Wichita (?)	4,220
49	29.5	2.3	Grayburg	Per	DL	Por	3,197	3,200	3	A	Grayburg	3,205
50	30.1	y	San Angelo	Per	DL	Por	2,650	2,825	y	A	Clear Fork	3,750
51	38	0	San Angelo	Per	S	Por	1,370	1,410	10	MC	Wichita (?)	3,972
52	27.8	y	Strawn	Pen	S	Por	1,415	1,430	10	AF	Ellenburger	2,074
53	39	0.1	Delaware Mt.	Per	S	Por	3,930	3,950	10	T	Delaware Mt.	4,165
54	38	0.1	Delaware Mt.	Per	S	Por	4,290	4,310	7	MC	Delaware Mt.	5,083
55	28	y	Clear Fork	Per	D	Por	4,870	5,002	y	x	Clear Fork	5,002
56	23	3.5	Clear Fork	Per	D	Por	2,800	3,000	50	MC	Wichita (?)	5,250
57	43	y	Data on producing formation and deepest zone tested included separately									
58	37	y	San Andres	Per	D	Por	2,280	2,310	y	A	Pre-Cambrian	5,745
59	26	y	Clear Fork	Per	D	Por	3,350	3,370	y	A	Pre-Cambrian	5,745

TABLE 1.—(*Continued*)

Line Number	*County*, Field	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[6]	To End of 1941	During 1941
	Pecos:					
60	3,800-foot pay	1941	320	0	[4]	
61	McKee sand	1940	3,100	0	[4]	
62	Waddell sand	1941	160	160	[4]	
63	Ellenburger	1941	40	0	[4]	
64	Apco-Warner	1939	720	0	154,255	89,328
65	Fromme	1939	290	80	71,709	34,401
66	Grassroots	1940	*x*	0	668	198
67	Heiner	1941	40	0	3,828	3,828
68	Jamison-Pollard	1941	40	0	21,200	21,200
69	Lehn	1939	1,200	0	290,809	134,733
70	Masterson	1927	190	0	919,636	58,531
71	Netterville	1934	1,600	0	368,558	30,098
72	Pecos Valley (high gravity)	1928	1,300	0	2,451,544[5]	239,696
73	Pecos Valley (low gravity)	1928	2,160	0	[5]	184,368
74	Richard (Prior)	1929	160	0	30,267	920
75	Shearer	1938	400	0	1,028,604	204,218
76	Taylor-Link	1929	2,100	0	7,060,921	700,930
77	Toborg	1928	1,314	0	6,948,883	518,730
78	Walker	1940	1,080	0	162,706	150,708
79	Wentz	1941	160	0	1,538	1,538
80	White and Baker	1935	684	1,676	191,693	80,061
81	Yates (sand)	1933	700	0	466,889	44,300
82	Yates (lime)	1926	20,000	0	259,871,229	5,605,546
83	*Pecos-Ward:* Payton	1937	1,770	0	2,538,407	473,242
84	*Reagan:* Barnhart	1941	640	0	14,372	14,372
85	Big Lake (2,400-foot pay)	1923	275	0	[4]	[4]
86	Big Lake (3,000-foot pay)	1923	3,000	0	[4]	[4]
87	Big Lake (Ordovician)	1928	640	0	98,277,352	2,020,591
88	*Reeves:* Anthony	1939	20	0	2,502	391
89	*Runnels:* Beddo	1938	50	0	52,117	28,179
90	Huddleston	1940	20	0	12,658	7,066
91	McMillan	1927	190	0	990,962	3,707
92	*Schleicher:* Opp	1939	40	0	2,595	0
93	Page	1939	160	1,000	32,281	9,400
94	*Scurry:* Sharon Ridge (restricted)	1938	3,400	0	613,476	522,850
95	*Scurry-Mitchell:* Sharon Ridge (shallow)[7]	1924	3,800	0	268,294	92,329
96	*Tom Green:* Funk	1940	20	0	360	60
97	*Upton:* Webb Ray (Cordova-Union)	1936	160	0	56,134	5,394
98	*Upton-Crane:* McCamey-Hurdle-Herrington-Crane Cowder	1925	20,000	0	57,790,072	3,788,241
99	*Ward:* Dobbs	1940	160	0	19,737	2,325
100	Estes	1936	4,500	2,000	12,529,019	1,945,822
101	Magnolia Sealy	1938	1,000	*y*	779,821	231,763
102	Magnolia Sealy South	1940	1,200	*x*	88,375	81,375
103	Monroe	1930	80	0	56,711	8,690
104	Quito	1940	160	*x*	*y*	*y*
105	Shipley	1928	320	0	3,723,582	563,498
106	Shipley (Deep)	1940	320	0	22,123	22,123
107	North Ward	1929	10,000	*y*	24,073,834	2,403,965
108	South Ward	1930	12,800	*y*	27,565,676	1,314,729
109	Spencer	1941	1,200	0	9,371	9,371
110	*Winkler:* Eaves	1936	320	0	541,116	158,796
111	Emperor	1936	2,000	360	2,721,382	424,186
112	Emperor Deep	1940	1,600	*y*	287,556	170,556
113	Halley	1935	820	10	860,852	118,208
114	Henderson	1935	2,800	0	5,305,591	876,548
115	Hendrick	1927	12,138	0	205,345,000	2,814,056
116	Kermit	1928	15,240	*y*	29,315,107	2,847,376
117	Keystone (Colby sand)	1935	7,000	*y*	2,989,687	1,186,435
118	Keystone (Lime)	1935	9,500	0	4,389,066	557,555
119	Leck	1927	960	*y*	3,916,902	195,605
120	Scarborough	1927	3,790	0	5,542,725	588,927
121	Weiner	1941	160	0	2,351	2,351
122	*Yoakum:* Ownby	1941	480	0	25,415	25,415
123	Waples-Platter	1939	600	0	41,348	21,933
124	West	1938	40	0	34,741	9,058

[5] Previous year's production not divided between high gravity and low gravity.

[7] Formerly Ira pool.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]
				During 1941		End of 1941			Number of Wells				
	To End of 1941	During 1941	Completed to End of 1941	Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift	Initial	Avg. at End of 1941	
60	[4]	*y*	4	4	0	4	4	0	4	0	*x*	*y*	
61	[4]	*y*	40	39	0	0	39	0	40	0	2,304	2,400	
62	[4]	*y*	6	6	0	0	3	3	2	1	*y*	*y*	
63	[4]	*y*	1	1	0	0	1	0	0	1	*y*	*y*	
64	*x*	*y*	11	4	0	0	11	0	10	1	*y*	1,580	
65	*x*	*y*	10	0	0	0	10	0	3	7	*x*	*y*	
66	0	0	3	0	0	0	3	0	0	3	*x*	*x*	
67	0.24	0.24	1	1	0	0	1	0	1	0	*y*	*y*	
68	*x*	*y*	1	1	0	0	1	0	1	0	*y*	*y*	
69	*x*	*y*	46	9	0	0	46	0	43	3	*y*	*y*	
70	*x*	*y*	24	2	0	0	24	0	0	24	*x*	*x*	
71	*x*	*y*	23	0	0	1	20	0	15	5	*x*	*y*	
72	*x*	*y*	102	0	1	0	101	0	43	58	*x*	*y*	
73	*x*	*y*	78	0	1	0	77	0	27	50	*x*	*y*	
74	*x*	*x*	7	0	0	2	2	0	0	2	*x*	*x*	
75	*x*	*y*	48	2	1	0	47	0	27	20	*x*	*y*	
76	*x*	*x*	109	15	3	0	109	0	8	101	*x*	*y*	
77	*x*	*x*	252	14	*y*	0	252	0	2	252	*x*	*x*	RP
78	*x*	*y*	39	34	0	0	39	0	32	7	843	735	
79	0.43	0.43	1	1	0	0	1	0	1	0	*y*	*y*	
80	*x*	*y*	18	6	0	0	18	3	18	0	850	845	
81	*x*	*y*	10	0	0	0	10	0	0	10	100	*x*	
82	119,155	1,173	559	1	0	4	555	0	521	38	700	529	
83	*x*	*y*	141	0	13	0	128	0	53	75	750	*y*	RP
84	23.8	23.8	2	2	0	0	2	0	2	0	*y*	*y*	
85	*x*	*x*	21	0	0	0	4	0	0	4	*x*	*x*	
86	*x*	*x*	261	0	1	3	182	0	0	182	*x*	*x*	
87	*x*	*y*	25	1	2	1	14	1	7	7	3,600	*y*	
88	*x*	*x*	1	0	0	1	0	0	0	1	*x*	*x*	
89	*x*	*x*	5	1	0	0	4	0	0	4	*y*	*y*	
90	*x*	*y*	2	0	0	1	1	0	1	0	*y*	*y*	
91	*x*	*x*	19	0	1	6	1	0	0	1	*y*	*y*	
92	*y*	*y*	1	0	0	0	1	0	0	1	*x*	*y*	
93	3,417	1,632	5	0	0	0	1	4	0	1	2,056	1,500 ±	
94	*x*	*y*	99	24	0	1	98	0	0	98	*x*	*x*	
95	*x*	*x*	65	42	0	3	62	0	0	62	*x*	*x*	
96	*x*	*x*	1	0	0	0	1	0	0	1	*x*	*y*	
97	*x*	*x*	5	0	2	0	2	0	0	2	*x*	*x*	
98	*x*	*x*	1,069	26	47	0	969	0	2	967	*x*	*x*	
99	*x*	*y*	1	0	0	0	1	0	0	1	*x*	*x*	
100	*x*	*y*	344	8	0	0	344	0	283	66	1,370	420	
101	*x*	*y*	55	0	0	0	55	0	33	22	1,360	1,400	
102	*x*	*y*	14	11	0	0	14	0	14	0	*y*	*y*	
103	*x*	*y*	2	0	0	0	2	0	2	0	*x*	*y*	
104	*x*	*y*	1	0	1	0	0	1	1	0	*x*	*y*	
105	*x*	*y*	120	7	0	0	120	0	10	110	*x*	*y*	
106	*x*	*y*	2	1	0	0	2	0	2	0	*y*	*y*	
107	*x*	*y*	414	55	0	0	414	0	281	133	1,400	*y*	
108	*x*	*x*	582	*y*	*y*	20*y*	582	3	217	365	1,370	300	
109	2.6	2.6	4	4	0	0	4	0	4	0	1,400	1,400	
110	*x*	*y*	7	0	0	0	7	0	2	5	*x*	*y*	
111	*x*	*y*	72	9	0	0	72	*y*	66	6	1,300	760	
112	*x*	*y*	48	13	0	0	48	0	41	7	836	279	
113	*x*	*y*	25	0	1	0	24	0	7	17	1,235	670	
114	*x*	*y*	139	0	0	0	139	0	131	8	1,450	1,285	
115	*x*	*y*	298	0	8	0	290	0	85	205	1,720	1,747	
116	*x*	*y*	848	0	21	0	827	0	285	542	1,450	359	SR
117	*x*	*y*	230	76	0	0	230	0	181	49	*y*	*y*	
118	*x*	*y*	91	7	0	0	91	0	67	24	*y*	*y*	
119	*x*	*y*	9	0	0	0	9	0	1	8	*y*	*y*	
120	*x*	*y*	134	2	0	0	134	0	91	43	1,450	737	SR
121	5.4	5.4	1	1	0	0	1	0	1	0	*y*	*y*	
122	0	0	5	5	0	0	5	0	5	0	*x*	*y*	
123	0	0	2	0	0	0	2	0	1	1	1,950	*y*	
124	*y*	*y*	1	0	0	0	1	0	0	1	*y*	*y*	

TABLE 1.—(*Continued*)

Line Number	Character of Oil		Producing Formation								Deepest Zone Tested to End of 1941	
							Depth, Avg. Ft.					
	Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent	Name	Age[e]	Character[f]	Porosity[g]	Top Prod. Zone	Bottoms Prod. Wells	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
60	35.2	*y*	Wichita	Per	D	Por	3,750	3,820	*y*	A	Pre-Cambrian	5,745
61	43	*y*	Upper Simpson	Ord	S	Por	5,320	5,350	25	F	Pre-Cambrian	5,745
62	40	*y*	Lower Simpson	Ord	S	Por	5,910	5,940?	25	A	Pre-Cambrian	5,745
63	40.6	*y*	Ellenburger	Ord	D	Por	5,920	5,932	*x*	A	Pre-Cambrian	5,745
64	41	*y*	Ellenburger	Ord	D	Cav	4,550	4,580	20	A	Pre-Cambrian	4,526
65	27	*y*	Queen	Per	S-D	Por	1,412	1,443	15	D	San Andres	1,674
66	17	0	Paluxy	Cre	S	Por	50	60	*y*	*y*	Devonian	6,473
67	35.8	*y*	Ellenburger	Ord	D	Por	5,382	5,389	*x*	*x*	Ellenburger	5,665
68	24.4	*y*	San Andres	Per	D	Por	2,037	2,041	4	*x*	San Andres	2,550
69	34	*y*	Queen	Per	S	Por	1,675	1,700	10	A	Grayburg	1,995
70	28	1.4	Queen	Per	S	Por	1,200	1,400	5	M	Pre-Cambrian	4,526
71	41	*y*	Yates sand	Per	S	Por	1,300	1,600	15	A	San Andres	2,550
72	38	1.6	Yates sand	Per	S	Por	1,875	1,950	15	A	San Andres	2,253
73	25	*y*	Yates sand	Per	S	Por	1,500	1,650	15	A	Ellenburger	5,665
74	17	0	Dewey Lake	Per	S	Por	1,380	1,397	10	*x*	San Andres	4,360
75	35	*y*	Seven Rivers	Per	S	Por	1,415	1,465	*y*	*y*	Pre-Cambrian	4,526
76	29	1.3	[6]	Per	D-S	Por	1,580	1,650	25	A	San Andres	1,845
77	19	2.1	Toberg	Cre	S	Por	400	445	15	AL	San Andres	1,400
78	31.2	1.4	Queen	Per	S	22	2,065	2,080	15	A	Ellenburger	9,811
79	33.7	*y*	Ellenburger	Ord	D	Por	4,307	4,383	20	*x*	Pre-Cambrian	4,493
80	31.5	1.4	Queen	Per	S-D	22	1,650	1,700	10	A	Ellenburger	9,811
81	32	1.5	Yates sand	Per	S	Por	900	1,100	15	AL	San Andres	1,852
82	30	1.6	San Andres	Per	D	Por	1,310	1,450	100	A	San Andres	1,938
83	33.5	1.1	Yates sand	Per	S	Por	2,000	2,080	40	A	San Andres	3,200
84	44.2	*y*	Ellenburger	Ord	D	Por	9,016	9,082	25	*x*	Ellenburger	9,294
85	35	0.3	Queen	Per	S	Por	2,375	2,500	40	A	Ellenburger	9,562
86	36	0.4	San Andres	Per	L-D	Por	2,960	3,000	60	AD	Ellenburger	9,562
87	44	0.18	Ellenburger	Ord	D	Por	8,200	8,900	*x*	A	Ellenburger	9,562
88	30	*y*	Upper Castile	Per	D	Por	1,618	1,630	*y*	*x*	Upper Castile	1,900
89	42	*y*	*y*	Pen	S	Por	2,366	2,388	22	N	*y*	*y*
90	39	*y*	Palo Pinto	Pen	L	Por	3,557	3,583	26	N	Palo Pinto	*y*
91	41	*y*	Graham	Pen	S	Por	2,550	2,562	12	N	*y*	*y*
92	34	*y*	Cisco	Pen	L	Por	4,045	4,081	15	*y*	*y*	*y*
93	41	*y*	Strawn	Pen	L	Por	5,485	5,560	50	A	Bend (?)	6,257
94	30	*y*	San Angelo and Clear Fork	Per	D & S	Por	2,250	2,450	*y*	A	Wichita	3,545
95	29	2	San Andres	Per	DL	Por	1,650	1,750	*y*	A	Wolfcamp	4,524
96	33	*y*	San Andres	Per	DL	Por	1,123	1,127	4	MC	Clear Fork	1,560
97	25	*y*	Grayburg	Per	DL	Por	2,060	2,150	*y*	A	San Andres	2,176
98	28	2.3	Grayburg	Per	DL	Por	2,250	2,300	30	A	Wichita	4,610
99	37	*y*	Queen	Per	S	Por	2,550	2,570	7	*y*	Grayburg (?)	2,600
100	34	1.2	Yates sand	Per	S & D	Por	2,450	2,950	50	A	Queen	3,274
101	32.7	*y*	Seven Rivers	Per	OD	Por	2,878	2,952	30	A	Queen	3,175
102	28	*y*	Seven Rivers	Per	OD	Por	2,890	2,910	15	A	Queen	3,277
103	29	0.14	Delaware sand	Per	S	Por	4,665	4,675	5	T	Delaware sand	4,692
104	*y*	*y*	Delaware sand	Per	S	Por	5,084	5,094	10	A	Delaware sand	5,130
105	34	1.8	Seven Rivers	Per	DS	Por	2,900	3,100	50	A	Ellenburger	9,187
106	32.2	0	Silurian	Sil	L	Por	7,018	7,075	*x*	*x*	Ellenburger	9,187
107	36	1	Yates sand	Per	D-S	Por	2,500	2,750	40	ML	Wichita (?)	4,825
108	32	1.3	Seven Rivers	Per	S	Por	2,300	2,525	40	ML	Wichita (?)	4,825
109	28	*y*	Seven Rivers	Per	OD	Por	2,930	2,960	20	A	Seven Rivers	2,990
110	26	*y*	Yates sand	Per	DS	Por	3,100	3,170	20	A	Seven Rivers	3,175
111	33	*y*	Yates sand	Per	S	Por	2,833	3,100	40	AC	Seven Rivers	3,145
112	*y*	*y*	Seven Rivers	Per	OD	Por	2,790	3,000	20	A	Seven Rivers	3,000
113	31.1	*y*	Yates sand	Per	S	Por	3,100	3,200	22	AC	San Andres	3,855
114	30	1.1	Seven Rivers	Per	OD	Por	3,025	3,075	30	A	Grayburg (?)	3,450
115	28	1.4	Seven Rivers	Per	OD	Por	2,600	2,900	*y*	A	San Andres	3,920
116	35	*y*	Yates sand	Per	DS	Por	2,825	3,200	10	A	Grayburg	3,414
117	36	*y*	Grayburg	Per	S	Por	3,215	3,313	*y*	A	San Andres	3,702
118	36.5	0.8	Grayburg and San Andres	Per	D & S	Por	3,210	3,360	*y*	A	San Andres	3,702
119	28	1.6	Seven Rivers	Per	OD	Por	3,000	3,100	*y*	A	San Andres	3,780
120	35	1.0	Yates sand	Per	DS	Por	2,800	3,050	10	A	Grayburg (?)	3,565
121	33.5	*y*	Queen	Per	S	Por	3,005	3,210	*y*	*x*	Queen	3,210
122	27	0.1	San Andres	Per	D	Por	5,235	5,360	70	A	San Andres	5,700
123	32.5	0.1	San Andres	Per	D	Por	5,200	5,300	25	A	San Andres	5,370
124	31	*y*	San Andres	Per	D	Por	5,168	5,255	10	MC	San Andres	5,255

[6] Three pay horizons: Yates sand, Queen and San Andres.

TABLE 2.—*Summary of Drilling Operations in West Texas*

Important Wildcats Drilled in 1941

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Blk.	Survey			
1	Andrews	23	A-42	P.S.L.	5,600	Recent	San Andres
2	Andrews	15	A-32	P.S.L.	8,000	Recent	Leonard
3	Andrews	32	10	U.L.	8,368	Recent	Ellenburger
4	Bailey	Labour 24	Leg. 173	Sutton County School Land	5,601	Recent	Clear Fork
5	Cochran	Labour 9	League 56	Oldham County School Ld.	7,000 P.B. 5,068	Recent	Clear Fork
6	Cochran	Labour 4	League 89	Lipscomb County Sch. Ld.	5,150 P.B. to 5,111	Recent	San Andres
7	Cochran	Labour 26	League 96	Mills County School Land	6,621	Recent	Clear Fork
8	Crane	12	3	H. & T.C.	6,146 P.B. to 6,015	Recent	Ellenburger
9	Crane	28	B-27	P.S.L.	5,660	Recent	Ellenburger
10	Crane	22	31	U.L.	10,659	Recent	Ellenburger
11	Crane	15	3	H. & T.C.	5,648	Recent	Ellenburger
12	Crockett	26	WX	G.C. & S.F.	6,300 P.B. 6,255	Cretaceous	Ellenburger
13	Crockett	37	GG	H.E. & W.T.	2,186	Cretaceous	San Andres
14	Crockett	48	UV	G.C. & S.F.	1,456	Cretaceous	San Andres
15	Crosby	3	D-15	W.T. & R.R.	4,054	Ogallala	Clear Fork
16	Dawson	36	M	E.L. R.R.	4,600	Recent	San Andres
17	Ector	4	45, T-1-N	T. & P.	6,431	Recent	Wichita
18	Ector	12	44, T-1-N	T. & P.	7,000	Recent	Wichita
19	Gaines	50	Ax	P.S.L.	11,108 P.B. 7,400	Recent	Ellenburger
20	Hale	17	K	T. & P.R.R.	6,766	Ogallala	Pre-Cambrian
21	Lubbock	25	A	J. H. Gibson	5,002	Ogallala	Clear Fork
22	Lynn	18	11	E.L. & R.R.	6,431	Recent	Clear Fork
23	Martin	Labour 10	League 260	Borden County School Land	7,701	Cretaceous	Clear Fork
24	Mitchell	49	16	S.P. & R.R.	8,002	Triassic	Ellenburger
25	Motley	127		J. H. Gibson	6,269	Ogallala	Pre-Cambrian
26	Pecos	8	105	H. & G.N.	1,583	Cretaceous	Yates Sand
27	Pecos	589		G.C. & S.F.	5,665 P.B. to 5,509	Cretaceous	Ellenburger
28	Pecos	43	11	H. & G.N.	4,493	Cretaceous	Ellenburger
29	Pecos	36	3	H. & T.C.	2,050 P.B. 2,041	Cretaceous	San Andres
30	Pecos	25	9	H. & G.N.	5,940 P.B. 5,932	Recent	Ellenburger
31	Pecos	Myrick strip	9	H. & G.N.	3,994 P.B. 2,320	Recent	Clear Fork
32	Pecos	22	9	H. & G.N.	5,945	Recent	Waddell Sand (Simpson)
33	Pecos	5	110	T.C. R.R.	4,526	Recent	Pre-Cambrian
34	Pecos	31	49 T-10	T. & P.	Drilling	Cretaceous	Delaware Mt.
35	Pecos	25	9	H. & G.N.	4,989 P.B. 4,470	Recent	McKee Sand (Simpson)
36	Pecos	31	9	H. & G.N.	5,745 P.B. 3,815	Recent	Pre-Cambrian
37	Reagan	3	48	V.L.	9,294 P.B. 9,082	Cretaceous	Ellenburger
38	Ward	53	34	H. & T.C.	2,990	Recent	Seven Rivers
39	Winkler	4	B-3	P.S.L.	8,445	Recent	Devonian
40	Winkler	7	B-11	P.S.L.	3,210	Recent	Queen
41	Yoakum	502	D	J. H. Gibson	5,348	Recent	San Andres

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1941

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Fuhrman Petr. Co.	40	0.08	1	175	20	Discovery West Fuhrman
2	Fullerton Oil Co.	682	0.25	1	0–40	60–10	Pay 6790 to 7400 ft.
3	Phillips Petr. Co.						Dry and abandoned
4	Broderick & Calvert et al.						Dry and abandoned
5	Atlantic Ref. Co.	849	0.42	5 c sq.	600	350	Tested formations below regular Slaughter field zone
6	Atlantic Ref. Co. & R. Rhodes	358 pump		⅝			Discovery; Rhodes pool
7	Livermore Drill. Co.						Dry and abandoned
8	Continental Oil Co.	83	0.10	5⁄16	275	25	Discovery well: Waddell sand Production S. Crane Co.
9	Gulf Oil Corp. 1-B Tubb	6,905	4.7	3 (tubing)	1,000–500	x	Discovery well of 1-B Area—South Sand hills
10	Gulf Oil Corp. 1-F Univ.						Dry and abandoned
11	Gulf et al. 17 Waddell	1,242	2.7	2	556	131	Discovery well 17 Waddell area South Sand Hills
12	Amerada 1-B Todd	85.3	0.004	½	0	260–0	Showed oil in Ellenburger
13	Inman & Harris	88-+ 6 hr.					Discovery well Clara Couch field
14	Wahlenmaier & Currie	196	Gas lift				Discovery well Bean field
15	G. Callahan & C. L. Wagner						Dry and abandoned
16	Ray Albaugh	181 pump					Discovery: Welch pool
17	Grisham & Delaney						Dry and abandoned
18	Stanolind						Dry and abandoned
19	A. G. Carter	511	0.41	½	750	200	Discovery Wasson's 3rd Pay 7055–7433
20	Humble Oil & Ref. Co.						Dry and abandoned
21	L. C. Harrison	160 pump	0.05				Discovery: Lubbock pool
22	Livermore Drill. Co.						Dry and abandoned
23	Magnolia Petr. Co.						Dry and abandoned
24	Humble Oil & Ref. Co.						Dry and abandoned
25	Humble Oil & Ref. Co.						Dry and abandoned
26	H. L. Cain & S. G. Dunn		0.96				Discovery gas well
27	Culbertson & Irwin Inc.	36		Gas lift			Discovery Heiner pool
28	Gulf Oil Corporation	263	0.34	2 tbg.	300	35	Discovery Wentz pool
29	Jamison & Pollard	193	x	4 (sq. outlet)	y	y	Discovery Jamison and Pollard
30	Magnolia-W. F. McKee	62 pump					Discovery: Ellenburger production Abell field
31	Magnolia 1-B St. Myrick	66	0.001	½	390–360	390–395	Discovery: Abell field "2300-ft. pay"
32	Magnolia 1 St. Sharp	92-P					Discovery: Abell field Waddell sand pay
33	Olson Drill. Co. & Bryce McCandless	2,416	7.73	¾	1,600	950	Discovery: First "pay" below Ellenburger
34	Pure Oil Co.			Testing at end of year			Discovery: Chancellor pool
35	Siemoneit Drill. Co.	265	0.12	½	580	250	Discovery: Abell field "3300-ft. pay"
36	Stanolind Oil & Gas Co.	346	xy	¼	1,400–880	1,400–500	Discovery: Abell field "3800-ft. pay"
37	Amerada Petr. Co.	1,122	2.4	1	175	200	Discovery: Barnhart pool
38	Stanolind	226	0.001	¼	275	275	Discovery: Spencer pool
39	Magnolia						Dry and abandoned
40	Sam Weiner	370	0.77	¾	350	y	Discovery Weinar pool
41	Livermore Drill. Co.	13	x	⅝	0–180	200–800	Discovery: Ownby pool

laid. The capacities of the main trunk lines out of the region were increased by pump installations, looping of lines, and larger pipe. The capacity of the trunk lines of the region is now approximately 440,000 bbl. of crude per day, an amount that is still much too small for the area.

Discoveries

There were 25 new discoveries throughout the district, including new "pays" found in previously producing fields. Of this number, 9 are from the pre-Permian and 16 from Permian rocks. These are listed in Table 3.

To single out particular discoveries as the most significant or the most important is a very difficult task. However, the following have been chosen as outstanding, from present information and present interpretation of the data in Table 3.

Outstanding Permian Discoveries.—The Lubbock County discovery, No. 1 Nairn of L. C. Harrison et al., in sec. 25, block A, J. H. Gibson survey, about 3½ miles northeast of the city of Lubbock, was completed as a producer in the Clear Fork at a depth of 5002 ft. On the official test Oct. 30, 1941, it pumped 160 bbl. of 28° gravity oil in 24 hr. plus 5 per cent water from a broken pay zone composed of finely granular and finely porous dolomite topped at 4870 ft. The well was shot with 465 qt. from 4885 to 5002 ft. and treated with 2000 gal. of acid. Although this field has not been extended as yet, the possibilities for this large area are very encouraging, in that the discovery lies 42 miles north of the Garza field, Garza County, and 39 miles east of the Slaughter field.

The Wasson "72" discovery well, Amon G. Carter No. 4-D Wasson, sec. 50, block AX, P.S.L. survey, was drilled to a depth of 11,108 ft., presumably in the Ellenburger, and plugged back to a depth of 7433 ft. The pay, which was topped at 7055 ft., is correlative with that in the Fullerton Petroleum Company's No. 1 Wilson in Andrews County, and is believed to be Wichita (Leonard) in age. On initial test in December, the well flowed 511 bbl. of 34° gravity oil in 24 hr. on gas lift, through ½-in. choke. Geological information on the well has not yet been released. This pay should be one of the outstanding future reserves in northern West Texas and part of southeastern New Mexico.

Table 3.—*New Discoveries during* 1941, *Including New "Pays" in Established Fields*

County	Field	Discovery Well	Producing Horizon
Andrews....	West Fuhrman	Fuhrman Petr. Co. No. 1 Lockhart-Brown	San Andres
Cochran....	Rhodes	Rhodes & Atlantic No. 1 Honolulu-Dean	San Andres
Crane.......	South Sand Hills	Continental Oil Co. No. 1 E. B. Jones	Simpson (Waddell)
Crane.......	South Sand Hills	Gulf Oil Corporation No. 1-B Tubb	Ellenburger
Crane.......	South Sand Hills	Gulf Oil Corporation No. 17 Waddell	Ellenburger
Crockett....	Clara Couch	Inman & Harris No. 1 Clara Couch	San Andres
Crockett....	Bean	Wahlenmaier & Currie No. 1 George Bean	San Andres
Dawson.....	Welch	Ray Albaugh No. 1 J. J. Handley	San Andres
Gaines......	Wasson "72"	A. G. Carter No. 4-D Wasson	Wichita
Lubbock....	Lubbock	L. C. Harrison et al. No. 1 Nairn	Clear Fork
Pecos.......		Cain & Dunn No. 1 Sun-Downs	Yates Sand
Pecos.......	Abell	Magnolia Petr. Co. No. 1 W. F. McKee	Ellenburger
Pecos.......	Abell	Magnolia Petr. Co. No. 1 State-Sharp	Simpson (Waddell)
Pecos.......	Abell	Magnolia Petr. Co. No. 1-B State-Myrick	San Andres
Pecos.......	Abell	Sicmoneit Drill Co. No. 1 Walsh et al.	Clear Fork
Pecos.......	Abell	Stanolind Oil & Gas Co. No. 1 Conry-Davis	Wichita
Pecos.......	Apco-Warner	Olson Drill. Co. & Bryce McCandless No. 1 Crockett	Pre-Ellenburger
Pecos.......	Heiner	Culbertson & Irwin Inc. No. 1 Heiner	Ellenburger
Pecos.......	Jamison & Pollard	Jamison & Pollard No. 6-DE Pecos Valley	San Andres
Pecos.......	Taylor-Link	Milton Unger No. 1 Shell-University	Queen
Pecos.......	Wentz	Gulf Oil Corp. et al No. 2 L. H. Millar	Ellenburger
Reagan.....	Barnhart	Amerada Pet. Corp. No. 1-RA University	Ellenburger
Ward.......	Spencer	Stanolind Oil & Gas Co. No. 1 Molly Spencer	Seven Rivers
Winkler.....	Weiner	Sam Weiner No. 1 S. B. Halley	Queen
Yoakum....	Owenby	Livermore Drill Co. No. 1 Owenby	San Andres

The Abell field, in northern Pecos County, had five new "pays" found in it during 1941 and now has more productive zones than any other field on the Central Basin Platform. Three of the newly discovered "pays" are from the Permian and two are from the pre-Permian. New "pays" from the Permian include San Andres (Penn-Goldsmith zone), San Andres (Holt equivalent) and Wichita (Tubb equivalent). Because the dolomite section is very porous, equivalent oil-bearing zones might be expected over the whole of the structure.

Important Pre-Permian Discoveries.—One of the most outstanding additions to the reserves of West Texas was the discovery of the Barnhart field in southeastern Reagan County. The discovery well, sec. 3, block 48, University Lands survey, was completed Oct. 1, 1941, at a plugged back depth of 9082 ft. On official test the well gauged 1122 bbl. of 44.2° gravity oil through 1-in. tubing choke on 2-in. tubing, with a gas-oil ratio of 2140:1 after an acid treatment of 5000 gal. The pay, which was topped at 9016 ft., comes from Ellenburger dolomite, from which some of the upper part has been removed by erosion. The pay is finely to coarsely crystalline dolomite with interstitial porosity, in contrast to most Ellenburger porosity, which usually is fractured and cavernous. There are approximately 60 ft. of porosity, of which about 25 ft. are thought to be effective pay.

PERMIAN	OCHOA	Dewey Lake
		Rustler
		Salado
	GUADALUPE	Tansill
		Yates
		Seven Rivers
		Queen
		Grayburg
	LEONARD	San Andres
		Clear Fork
		Wichita
	WOLFCAMP	Wolfcamp
PENNSYLVANIAN		Cisco Canyon Strawn Bend
MISSISSIPPIAN		Chester

DEVONIAN	Devonian	
SILURIAN	Niagaran	
ORDOVICIAN	Montoya	
	Simpson	McKee Sand Waddell Sand
	Ellenburger	
CAMBRIAN	Unnamed conglomeratic sand	
PRE-CAMBRIAN	Pre-Cambrian	

TABLE 4.—CORRELATION CHART.

New areas of Ellenburger and Simpson production along the "Crane County Ridge" were opened by the Gulf Oil Corporation's No. 1-B Tubb and No. 17 Waddell, which produce from the Ellenburger, and the Continental Oil Company's No. 1 E. B. Jones, which produces from the Waddell sand of the Simpson group. Flank production from the McKee and Waddell sands and production on the top of this ridge from the Ellenburger mark this structural feature as one of our large Ordovician reserves. The production is relatively shallow (5650 ft.) and the wells are usually very large (10,000-bbl. wells being not uncommon).

The shallowest Ellenburger production in West Texas was discovered in No. 2 L. H. Millar, Gulf Oil Corporation et al., sec. 43, block 11, H. & G. N. survey. This well originally was completed in December at a total depth of 4383 ft., for a flow of 263 bbl. of 33.7° gravity oil with a gas-oil ratio of 2757:1, through 2-in. tubing, after treatment with 10,000 gal. of acid. Production did not hold up, so the well was drilled to granite, where it became the second well in West Texas to show oil in the sand and conglomeratic section beneath the Ellenburger. The other well, Olson & McCandless' No. 1 Crockett, sec. 5, block 110, H. & G. N. survey, at the southwest end of Apco-Warner field, northern Pecos County, reported an increase of about 75 bbl. per hour from the conglomerate section beneath the Ellenburger, at a depth of 4523 to 4526. This section should be kept in mind for future exploration, because of the presence of numerous granite knobs in West Texas and southeastern New Mexico.

Two new Ordovician "pays" were found in the Abell field; Waddell sand (Lower Simpson) and in the Ellenburger.

EXTENSIONS

At least three fourths of the fields in West Texas were extended some during 1941. However, the most active was the Slaughter field, where 648 wells were drilled during 1941, giving it a size of 55,000 acres and thereby making it almost as large as the Wasson field. The following fields were extended considerably: Abell, Emma, Foster, Johnson, Noelke, North Cowden, Sand Hills, Seminole, Todd, Walker, and Wasson.

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Oil and Gas Development in West Virginia during 1941

By David B. Reger,* Member A.I.M.E.

The expansion of the previously discovered gas pools and an intensified search for additional pools in the Oriskany and deeper sands were the principal petroleum activities in West Virginia during 1941. One small oil pool was discovered and another was considerably extended. One small gas pool was discovered, several isolated well discoveries were expanded into definite pools, and various recognized pools were substantially increased. The proved oil territory of the state was increased about 600 acres and the proved gas territory about 45,000 acres. The new discoveries of oil did not equal withdrawals but gas reserves added were greater than gas withdrawals.

Oil activity, as in the past several years, was slight because of unfavorable crude prices. Most operators prefer to leave oil in the ground rather than to drill for it without a better return. Gas activity increased greatly because of better demand, even though the price of gas did not improve. The account of operations, as gathered from trade journals and other reporting services, shows that 838 new wells were drilled, resulting in 114 new oil wells with 2606 bbl. of daily new production; 558 new gas wells with 949,226,000 cu. ft. of daily open flow; and 166 dry holes. Also, 86 old wells were drilled to deeper sands with 9 bbl. and 56,030,000 cu. ft. of added production. On the new wells the oil average was 22.86 bbl. per well per day; and the gas average was 1,701,000 cu. ft. per well per day. On new wells the ratio of dry holes to completions was 13.61 per cent. On deeper drilling to other sands the ratio of failures was 15.12 per cent.

From an exploratory standpoint one strictly new oil pool (Higginbotham Run) was opened in Kanawha County and one strictly new gas pool (Lost Run) in Taylor County. One entirely isolated wildcat gave commercial Oriskany-sand gas production and may open a pool. Various other wildcats greatly extended the boundaries of known Oriskany-sand gas pools and various others may have opened new pools in the shallow sands. On the other hand, various Oriskany tests in Harrison, Monongalia, Roane and Wood Counties were dry and all five tests to the White Clinton sand (Sil.) in Boone, Harrison, Kanawha and Wood Counties failed to find commercial production.

The principal oil wells completed, by counties, were: Calhoun, 24; Clay, 7; Gilmer, 6; Hancock, 9; Kanawha, 9; Pleasants, 10; and Ritchie, 14. Production for the year was estimated by the *Oil Weekly* as 3,421,000 bbl., compared with U. S. Bureau of Mines final figures of 3,444,000 bbl. in 1940. The leading counties in gas-well completions were: Boone, 32; Braxton, 19; Cabell, 16; Calhoun, 46; Clay, 20; Gilmer, 37; Jackson, 94; Kanawha, 82; Lincoln, 17; Putnam, 46; Ritchie, 33; Upshur, 20; and Wayne, 33. Production for the year is estimated by the author as 210,000,000,000 cu. ft., as compared to the U. S. Bureau of Mines' final figures of 188,751,000,000 cu. ft.* in 1940.

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* Consulting Geologist, Morgantown, W. Va.

* The public Service Commission of West Virginia reports (by letter) 193,343,584,000 cu. ft.

Various pipe lines of considerable sizes and extent were built to handle new gas developed in Jackson, Braxton and Upshur Counties. One additional compressor station was built.

The price of oil increased from $1.74 in January to $2.34 per bbl. at the end of the year. The price of gas at the well mouth did not improve, having declined to 12.3¢ per 1000 cu. ft. in 1940 and having no material change in 1941, but the demand was substantially greater.

Rotary equipment was used for the first time in the drilling of two deep holes in Harrison and Lewis Counties. The test in Harrison was carried to a record depth of 10,018 ft. This well was dry but the test in Lewis County developed Oriskany sand (L. Dev.) gas production. Extensive geophysical exploration for possible deep oil sands was in progress during the year in Wetzel and Tyler Counties, but no deep wells were drilled.

GENERAL STATE OF INDUSTRY

The leasing of land increased considerably during the year. Statistics are not available from any source but it is probable that 5,000,000 acres may be under lease. The proved oil reserve, estimates of which differ greatly, has slightly declined because the new discoveries did not equal withdrawals. The proved gas reserve has increased slightly, owing to the substantial additions of new territory.

Up to the end of 1941 about 64,770 oil and gas wells had been completed. During the year 114 oil wells and 558 gas wells were completed and 916 wells were abandoned because of nonproductivity or exhaustion. At the end of the year about 17,382 oil wells and about 13,878 gas wells were producing. Production statistics are given in Table 1.

PRINCIPAL AREAS OF ACTIVITY

In Boone County drilling was active but operations were mainly routine. A substantial quantity of new gas (20,002,000 cu. ft.) was found. On Bull Creek, Peytona district, one small Oriskany-sand well was drilled but two other tests of this sand failed. One well reached the White Clinton sand (Sil.) but had only a show. In Sherman and Crook districts two wildcats on the waters of Pond Fork, drilled to the upper sands, failed to get commercial production.

TABLE 1.—*Production Statistics, West Virginia*

Period	Oil, Bbl.	Average Oil per Well Daily, Bbl.	Gas, Millions Cu. Ft.	Average Gas per Well per Day, Cu. Ft.
To end of 1941	416,852,000		6,895,777	
During 1940	3,444,000[a]	0.54	188,751[a]	38,027
During 1941	3,421,000[b]	0.54	210,000[c]	41,457

[a] U. S. Bureau of Mines, final figures.
[b] *Oil Weekly*, estimate.
[c] Author's estimate.

In Braxton County only 19 wells out of 41 completions had commercial gas. Two of the six wildcats drilled had small production but the Morrison discovery in Holly district northeast of Sutton is already discounted by four dry holes in the same locality. A small Gordon sand gas well, in Salt Lick District northeast of Falls Mill, is of questionable importance. Attempts to extend the Villa Nova pool farther northeastward in Birch district were quite unsuccessful, although there were good results on the south in Clay County, as will be discussed later.

In Calhoun County the results of drilling were uniformly good, there being only three dry holes out of 73 completions. The 24 new oil wells had 452 bbl. of daily production and the 46 new gas wells had 30,029,000 cu. ft. of open flow. No wildcats were drilled but the Sycamore oil pool, of Sherman district, was considerably extended. At the end of 1940 this pool had only seven oil wells but at the end of 1941 it had 17 oil wells, two gas wells, one dry hole and eight uncompleted wells. Production is from the Big Injun sand (L. Mis.) with an average initial of about 20 bbl. per well. About 500 additional acres were proved in 1941, making the total pool area about 1000 acres.

In Gilmer County 55 new wells were drilled and five old ones were deepened, 12 of the new and one of the old being dry. Two wildcats were drilled, one of which, the Edwards No. 1 in Glenville district northwest of Dusk, was a small gas well in the Big Injun sand.

In Harrison County a slight amount of routine drilling was done and a deep exploratory hole was completed, as will be discussed under Development in Oriskany Sand.

Jackson County led the entire state both in the number of new completions and in the amount of new gas production. Most of the drilling was to the Oriskany sand.

Kanawha County fell slightly behind Jackson in the number of new completions and very much behind in the amount of new gas found. Most of the new gas came from the Oriskany. In this county the Oriskany exploration led to the discovery of the Higginbotham Run oil pool, in Poca district, 2 miles northeast of Carney. The discovery well, G. W. Burdette No. 1, by South Penn Natural Gas Co., was completed in September 1940 for only 10 bbl. of oil and 1,513,000 cu. ft. of gas in the Big Lime (L. Mis.), but in 1941 several additional wells were drilled. At the end of the year there were six oil wells, one dry hole and eight other tests in progress. Initial oil production totaled 1080 bbl. per day, or 180 bbl. per well; and two wells had substantial quantities of gas. Most of the wells have been acidized with good results. The pool is small, covering only about 100 acres and without much hope of extension, as many deeper wells have been drilled in adjacent territory. Even so this is the best discovery in the Big Lime in West Virginia.

In Lewis County little drilling was done, but a small Oriskany sand gas well was discovered by rotary drilling.

In Lincoln County various new gas wells were drilled and numerous shallow gas wells were deepened to the Brown shale (M. Dev.) with good results. The Spurlockville gas pool of Jefferson district, discovered many years ago but not actively followed up, had four new gas wells in 1941 and four wells were uncompleted. New proved territory was about 1000 acres. Gas is found in the Berea sand (L. Mis.) and Brown shale (M. Dev.). Average open flows are about 600,000 cu. ft. and rock pressure about 500 lb. One unsuccessful test has been drilled to the Oriskany sand (L. Dev.).

In Logan County a few new gas wells were drilled; one was a second test within the city limits of Logan and reported as a Weir sand (L. Mis.) producer with 223,000 cu. ft. This sand has not been generally productive elsewhere in the county.

In Mingo County five wells were drilled, resulting in five gas wells with 7,312,000 cu. ft. of open flow.

In Monongalia County, Battelle district, in old territory a mile west of Wadestown, the Ada E. Shriver No. 1-3615, by Manufacturers Light & Heat Co., was drilled to the Gordon Stray sand (U. Dev.) and gauged 8,500,000 cu. ft., but was flooded out by salt water in a few days. Deeper drilling to the Bayard sand (U. Dev.) found 719,000 cu. ft. in this lower pay.

In Pleasants County some additional drilling was done in the Maxwell gas pool of McKim district. In the three years 1939 to 1941, inclusive, 11 wells have been completed, resulting in six gas wells, two oil wells and three dry holes, with production from the Salt (L. Pen.) Maxton (U. Mis.), Keener (L. Mis.) and Big Injun (L. Mis.) sands. Generally, only one or two sands produce in any single well.

The average initial gas volume has been about 234,000 cu. ft. per well and the rock pressure about 440 lb. At the end of 1940 about 300 acres appeared to be proved and at the end of 1941 about 200 additional acres had been added.

In Putnam County, Curry district, the Trace Fork gas pool continued to be active. At the end of 1940 the pool had 26 gas wells and one dry hole. In 1941 there were 42 completions, with 38 gas wells, one oil well and three dry holes. Eight additional wells were drilling at the end of this year. Gas is found mostly in the Salt (L. Pen.), Big Lime (L. Mis.), and Berea (L. Mis.) sands. In 1941 the initial average volume of gas per well per day was about 864,000 cu. ft. and the rock pressure about 520 lb. At the end of 1940 the pool contained about 10,000 acres of proved gas territory, and at the end of 1941 it had increased to about 15,000 acres. Only a few wells have been drilled to the Brown shale (M. Dev.), which eventually may furnish much additional production in this pool.

In Putnam County, Union district, Oriskany sand (L. Dev.) gas production is now being found.

In Ritchie County there was the usual amount of routine drilling; 72 new wells were completed, resulting in 14 oil wells with 197 bbl. of initial production; 33 gas wells with 13,517,000 cu. ft. of open flow, and 25 dry holes. Eight wells were deepened and five of these produced additional gas.

In Roane County the results for the year were not very good. Out of 19 completions there were six oil wells with 132 bbl. of new production, four gas wells with 1,771,000 cu. ft. of open flow, and nine dry holes. A considerable amount of the drilling was to the Salt sand (L. Pen.) in the Flat Fork oil and gas pool of Harper district, where there were 11 completions with five oil wells, two gas wells and four dry holes. At the end of 1941 six wells were drilling in this pool. No appreciable amount of new proved acreage was added to the pool's limits. A deep Oriskany test in Walton district resulted in salt water.

In Taylor County, Booths Creek district, the Lost Run gas pool was opened on the eastern slope of the Chestnut Ridge anticline, with production from the Big Injun sand (L. Mis.). In this territory an old Big Lime (L. Mis.) well, completed many years ago, had some gas but the discovery was never followed up. In 1941 there were six completions with four gas wells and two dry holes. The average initial open flow is about 242,000 cu. ft. per well. Only about 100 acres have been definitely proved, but two additional wells were drilling at the end of the year.

In Upshur County drilling increased materially and 20 gas wells were completed out of 26 tests drilled. The Lorentz gas pool, of Buckhannon district, was more active than any other. This pool was opened late in 1940 by the drilling of four small gas wells, and in 1941 there were 11 completions with 10 gas wells and one dry hole. Production is mainly in the Benson sand (U. Dev.), but partly in the Fifty-foot (U. Dev.). The wells average about 300,000 cu. ft. of initial open flow and about 1200 lb. of rock pressure. At the end of the year the proved territory had been increased about 1000 acres, and two wells were drilling.

In the southern end of this county three small pools are being developed. The Rock Cave gas pool, in Banks district, was opened in 1940 with the completion of two gas wells. In 1941 there were three additional gas wells and no dry holes. Production is variously reported in the Big Injun and Squaw sands (L. Mis.), and in the Gordon and Benson sands (U. Dev.). Initial open flow averages about 250,000 cu. ft. and rock pressures about 350 lb. The proved territory is about 1000 acres, half of which may be credited to 1941. In Meade district the Holly Grove gas pool, discovered in 1924 but not actively exploited for several years, had six gas wells and one dry hole at the end of 1940. In 1941 there were completed two additional gas wells and one dry hole and one well was drilling. Production is reported from the Gordon, Fourth, Fifth, Bayard, Elizabeth, Riley and Benson sands (all U. Dev.), but only one or two of these yield gas in a single well. Initial open flows average about 330,000 cu. ft. and initial rock pressures about 570 lb. The territory proved in 1941 was about 500 acres, bringing the total up to about 1000 acres. In Meade district, also, drilling increased in the Evergreen gas pool. Discovered in 1928, this pool has six gas wells, two dry holes and about 2000 proved acres at the end of 1940. In 1941 the additions were five gas wells, two dry holes and about 500 acres of new proved territory; and three wells were drilling at the end of the year. Gas is variously reported from the Gordon, Bayard, Riley and Benson sands (all U. Dev.). Initial open flow has averaged about 480,000 cu. ft. and initial rock pressure about 620 pounds.

In Wayne County the Wayne gas pool, of Union district, was more active than any other. At the end of 1940 this pool had 30 gas wells, four dry holes and covered about 11,000 acres. In 1941 there were 19 additional gas wells, three more dry holes, and three uncompleted wells, but no additional acres were proved. Production is mainly from the Brown shale (M. Dev.), with an occasional Berea sand (L. Mis.) well. The wells of 1941 averaged about 197,000 cu. ft. of initial open flow and about 432 lb. of rock pressure.

In Wetzel County there was activity in the Newdale gas pool of Proctor district. Ten wells were completed, of which four were commercial gassers and six were dry holes; and three wells were drilling at the end of the year. About 500 acres of new proved territory was added. Production in this pool, the complete history of which is not on file with the author, is partly from the Maxton sand (U. Mis.) and partly from the Gordon (U. Dev.). Initial open flows have ranged from 100,000 to 10,000,000 cu. ft. and initial rock pressures from 200 to 1000 lb. Fair averages appear to be about 3,000,000 cu. ft. and 800 lb. In Grant district of this county a large Big Injun sand (L. Mis.) oil well, Mike Barr 6-1565 by Carnegie Natural Gas Co., was completed in old territory about one mile southwest of Mobley. This well, which was drilled for gas but which came in as a 221-bbl. oil well, has been transferred to Hope Construction and Refining Co., owner of the oil rights.

SUMMARY OF EXPLORATION

Table 2 gives a summary of important wildcat or exploratory wells drilled during 1941, together with some others that have revealed unexpected deeper production in old fields.

DEVELOPMENT IN ORISKANY SAND

Drilling to the deep Oriskany sand (L. Dev.) continued to be active and furnished 75 per cent of the new gas discovered during the year. In Boone County, Peytona district, three wells were completed in this sand, only one of which had a small Oriskany production. In Harrison County, Grant district, a rotary test 10,018 ft. deep was drilled through both the Oriskany and the White Clinton (Sil.) and failed to find commercial production in either of these sands (Table 2). In Jackson County, various districts, 97 wells were completed to the Oriskany and resulted in 94 gas producers and only three dry holes, as summarized in Table 3. At the end of the year 85 wells were drilling. Average initial open flow was 5,800,000 cu. ft. per well and rock pressures about 1700 lb. The Buttermilk-Sandyville gas pool of Ravenswood and Ripley districts, which had only 1200 acres of proved territory at the end of 1940, increased by about 14,800 acres in 1941, making the total proved territory

TABLE 2.—*Important Wildcats Drilled in West Virginia during* 1941

No.	County	Magisterial District	Location		Total Depth, Ft.	Surface Formation
			Lat.	Long.		
1	Boone	Crook	5.13 mi. S. of 38° 00′	2.49 mi. W. of 81° 40′	2,919	Pen-Kanawha
2	Boone	Washington	0.81 mi. S. of 37° 55′	4.50 mi. W. of 81° 40′	2,990	Pen-Kanawha
3	Braxton	Birch	3.12 mi. S. of 38° 40′	0.72 mi. W. of 80° 50′	2,854	Pen-Conemaugh
4	Braxton	Holly	4.76 mi. S. of 38° 45′	0.37 mi. W. of 80° 40′	2,174	Pen-Conemaugh
5	Braxton	Otter	2.40 mi. S. of 38° 50′	3.73 mi. W. of 80° 40′	2,196	Pen-Monongahela
6	Braxton	Salt Lick	5.76 mi. S. of 38° 50′	0.71 mi. W. of 80° 30′	1,917	Pen-Allegheny
7	Braxton	Salt Lick	3.66 mi. S. of 38° 50′	1.72 mi. W. of 80° 30′	4,335	Pen-Allegheny
8	Braxton	Salt Lick	1.24 mi. S. of 38° 50′	3.35 mi. W. of 80° 40′	2,090	Pen-Monongahela
9	Clay	Buffalo	3.85 mi. S. of 38° 35′	3.18 mi. W. of 80° 50′	2,387	Pen-Conemaugh
10	Clay	Otter	4.93 mi. S. of 38° 40′	4.17 mi. W. of 80° 00′	2,074	Pen-Conemaugh
11	Gilmer	Center	1.73 mi. S. of 38° 55′	4.13 mi. W. of 80° 45′	2,197	Pen-Conemaugh
12	Gilmer	Glenville	3.11 mi. S. of 38° 55′	1.20 mi. W. of 80° 45′	2,137	Pen-Monongahela
13	Harrison	Grant	0.57 mi. S. of 39° 10′	4.29 mi. W. of 80° 15′	10,018	Pen-Conemaugh
14	Jackson	Ravenswood	3.80 mi. S. of 38° 55′	2.60 mi. W. of 81° 35′	5,424	Perm-Dunkard
15	Jackson	Ravenswood	3.95 mi. S. of 39° 00′	0.26 mi. W. of 81° 35′	5,170	Perm-Dunkard
16	Jackson	Ravenswood	3.29 mi. S. of 39° 00′	2.39 mi. W. of 81° 35′	5,001	Perm-Dunkard
17	Jackson	Ravenswood	1.69 mi. S. of 38° 55′	2.95 mi. W. of 81° 35′	4,988	Perm-Dunkard
18	Jackson	Ravenswood	0.47 mi. S. of 38° 55′	2.92 mi. W. of 81° 35′	5,361	Perm-Dunkard
19	Jackson	Ripley	4.11 mi. S. of 38° 45′	1.29 mi. W. of 81° 40′	5,280	Perm-Dunkard
20	Jackson	Ripley	1.53 mi. S. of 38° 50′	3.71 mi. W. of 81° 35′	5,210	Perm-Dunkard
21	Jackson	Ripley	5.31 mi. S. of 38° 55′	3.25 mi. W. of 81° 35′	5,142	Perm-Dunkard
22	Jackson	Ripley	3.03 mi. S. of 38° 45′	4.52 mi. W. of 81° 35′	5,029	Perm-Dunkard
23	Jackson	Ripley	0.55 mi. S. of 38° 40′	3.72 mi. W. of 81° 35′	5,228	Perm-Dunkard
24	Jackson	Ripley	0.88 mi. S. of 38° 40′	0.08 mi. W. of 81° 40′	5,334	Perm-Dunkard
25	Jackson	Ripley	0.20 mi. S. of 38° 40′	1.30 mi. W. of 81° 40′	5,333	Perm-Dunkard
26	Jackson	Ripley	2.03 mi. S. of 38° 40′	3.61 mi. W. of 81° 35′	5,049	Perm-Dunkard
27	Jackson	Ripley	2.56 mi. S. of 38° 50′	3.52 mi. W. of 81° 35′	5,176	Perm-Dunkard
28	Jackson	Ripley	2.88 mi. S. of 38° 50′	4.53 mi. W. of 81° 35′	5,050	Perm-Dunkard
29	Jackson	Ripley	5.42 mi. S. of 38° 45′	4.08 mi. W. of 81° 35′	5,232	Perm-Dunkard
30	Jackson	Washington	3.90 mi. S. of 38° 40′	3.35 mi. W. of 81° 30′	5,332	Pen-Monongahela
31	Jackson	Washington	0.51 mi. S. of 38° 50′	1.44 mi. W. of 81° 35′	5,183	Perm-Dunkard
32	Jackson	Washington	0.40 mi. S. of 38° 45′	3.44 mi. W. of 81° 35′	5,087	Perm-Dunkard
33	Kanawha	Elk	2.97 mi. S. of 38° 30′	2.01 mi. W. of 81° 30′	6,500	Pen-Conemaugh
34	Kanawha	Elk	5.23 mi. S. of 38° 25′	3.38 mi. W. of 81° 15′	4,215	Pen-Kanawha
35	Kanawha	Poca	4.27 mi. S. of 38° 35′	1.37 mi. W. of 81° 30′	6,671	Pen-Conemaugh
36	Lewis	Freemans Creek	0.29 mi. S. of 39° 05′	1.64 mi. W. of 80° 30′	7,325	Pen-Conemaugh
37	Mason	Lewis	0.08 mi. S. of 38° 50′	0.09 mi. W. of 82° 05′	3,415	Pen-Conemaugh
38	Monongalia	Morgan	0.45 mi. S. of 39° 35′	1.19 mi. W. of 79° 50′	7,684	L. Mis-Pocono
39	Nicholas	Jefferson	0.04 mi. S. of 38° 20′	4.50 mi. W. of 81° 00′	2,214	Pen-Kanawha
40	Putnam	Curry	0.59 mi. S. of 38° 25′	0.74 mi. W. of 82° 00′	4,070	Pen-Conemaugh
41	Putnam	Teays Valley	3.88 mi. S. of 38° 35′	0.19 mi. W. of 82° 00′	2,480	Perm-Dunkard
42	Putnam	Union	2.55 mi. S. of 38° 40′	2.76 mi. W. of 81° 40′	5,254	Perm-Dunkard
43	Roane	Walton	1.64 mi. S. of 38° 35′	3.38 mi. W. of 81° 20′	5,503	Pen-Conemaugh
44	Taylor	Booths Creek	2.14 mi. S. of 39° 25′	1.48 mi. W. of 80° 05′	2,505	Pen-Allegheny
45	Upshur	Meade	3.46 mi. S. of 38° 55′	4.14 mi. W. of 80° 10′	2,128	Pen-Allegheny
46	Wayne	Lincoln	4.81 mi. S. of 38° 05′	3.22 mi. W. of 82° 25′	2,690	Pen-Kanawha
47	Wayne	Lincoln	4.35 mi. S. of 38° 10′	1.68 mi. W. of 82° 25′	3,298	Pen-Conemaugh
48	Wetzel	Grant	2.28 mi. S. of 39° 35′	3.65 mi. W. of 80° 30′	2,355	Perm-Dunkard
49	Wood	Tygart	5.12 mi. S. of 39° 15′	3.63 mi. W. of 81° 30′	6,297	Perm-Dunkard

TABLE 2.—(*Continued*)

No.	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day Oil, Bbl.	Initial Production per Day Gas, M Cu. Ft.	Tubing or Casing Pressure, Lb. per Sq. In.	Remarks
1	L. Mis-Pocono	Westmoreland, Inc.	Westmoreland, Inc., 1	0	58	?	Berea gas show; abandoned
2	L. Mis-Pocono	Westmoreland, Inc.	Westmoreland, Inc., 2	0	119	?	Berea gas show; abandoned
3	L. Mis-Pocono	South Penn Natural Gas Co.	C. H. Juergens, 1	0	0	0	Dry through Berea
4	U. Dev-Catskill	Robinson and Weaver	A. L. Morrison, 1	0	295	750	Gordon Stray gas well
5	L. Mis-Pocono	Pittsburgh & W. Va. Gas Co.	Ward Perrine, 1-7805	0	63	?	Big Injun show; abandoned
6	L. Mis-Pocono	Geo. Jackson Gas Co.	M. J. Bosley, 1-13	0	0	0	Dry through Big Injun
7	U. Dev-Chemung	Pittsburgh & W. Va. Gas Co.	Jessie C. Norman, 1-7750	0	81	765	Big Injun and Gordon gas well
8	L. Mis-Pocono	Pittsburgh & W. Va. Gas Co.	J. B. Reed, et al., 1-7806	0	0	0	Dry through Big Injun
9	L. Mis-Pocono	Pittsburgh & W. Va. Gas Co.	Norman Goad, et al., 1-7818	0	0	0	Dry through Big Injun
10	L. Mis-Pocono	Pittsburgh Oil & Gas Co.	Hugh H. Boggs, 1	0	0	0	Dry through Big Injun
11	L. Mis-Pocono	McCall Drilling Co.	Elmer Furr, 1-180	0	0	0	Dry through Big Injun
12	L. Mis-Pocono	W. H. & L. E. Mosser	L. D. Edwards, 1	0	200	340[2]	Big Injun gas well
13	Sil-Queenston	Hope Natural Gas Co.	C. S. Gribble, 2-8517	0	0	0	Dry through White Clinton
14	L. Dev-Oriskany	Columbian Carbon Co.	F. F. Starcher, et al., 1-GW 466	0	16,696	1,810[7]	Oriskany gas well
15	L. Dev-Oriskany	Columbian Carbon Co.	F. L. Roliff, et al., 1	0	0	0	Oriskany salt water
16	L. Dev-Oriskany	Joe Rubin	H. A. & H. O. Maddox, 1	5	400	?	Oriskany oil and gas well
17	L. Dev-Oriskany	Columbian Carbon Co.	J. E. Sweezy, et al., 1-GW 476	0	15,267	1,830[9]	Oriskany gas well
18	L. Dev-Oriskany	Columbian Carbon Co.	J. H. Boggess, et al., 1	0	4,500	1,860[10]	Oriskany gas well
19	L. Dev-Oriskany	United Carbon Co.	B. B. Meadows, 1-875	0	455	1,740[4]	Oriskany gas well
20	L. Dev-Oriskany	United Carbon Co.	D. H. Hyre, 1-891	0	5,628	1,890[4]	Oriskany gas well
21	L. Dev-Oriskany	McIntosh & Grimm	Austin Raines, et al., 1	0	9,980	1,875[2]	Oriskany gas well
22	L. Dev-Oriskany	United Fuel Gas Co.	D. J. Rogers, et al., 1-5011	0	7,117	?	Oriskany gas well
23	L. Dev-Oriskany	United Carbon Co.	Eliz. W. Perkins, et al., 7-945	0	5,173	1,830[5]	Oriskany gas well
24	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	J. L. McLean Hrs., 8-972	0	2,150	1,820[3]	Oriskany gas well
25	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	J. L. McLean Hrs., 9-976	0	0	0	Dry through Oriskany
26	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	The Putnam Co., 20-985	0	8,771	?	Oriskany gas well
27	L. Dev-Oriskany	United Fuel Gas Co.	J. B. Heilman, 1-5029	0	7,465	1,865[4]	Oriskany gas well
28	L. Dev-Oriskany	United Carbon Co.	Marshall Brown, 1-956	0	2,676	1,720[2]	Oriskany gas well
29	L. Dev-Oriskany	United Carbon Co.	P. C. Green, 1-973	0	7,556	1,840[2]	Oriskany gas well
30	L. Dev-Oriskany	Godfrey L. Cabot, Inc.	A. C. Good, 1-986	0	700	?	Oriskany gas well
31	L. Dev-Oriskany	Hope Natural Gas Co.	O. C. Parsons, 1-8586	0	0	0	Oriskany salt water
32	L. Dev-Oriskany	Columbian Carbon Co.	C. W. Starcher, 1-	0	15,991	1,900	Oriskany gas well
33	Sil-White Medina	Columbian Carbon Co.	Copenhaver Hrs., 1-GW 327	0	76	651[1]	Oriskany gas well drilled deeper; White Clinton gas show
34	L. Mis-Pocono	Delmos Hill	O. D. Hill, 1	0	0	0	Dry through Berea
35	Sil-White Medina	Columbian Carbon Co.	John Price, 1-GW 434	0	0	0	Oriskany gas well drilled deeper, dry through White Clinton
36	L. Dev-Oriskany	Hope Natural Gas Co.	Alfred Woofter, 4-8555	0	474	2,300[8]	Oriskany gas well
37	M. Dev-Hamilton	Point Pleasant Oil & Gas Co.	K. B. & Joseph Lunsford, 1-1	0	0	0	Dry through Brown shale
38	L. Dev-Oriskany	Hope Natural Gas Co.	H. C. Greer, et al., 1-8526	0	100	?	Huntersville Chert gas show and salt water; Dry in Oriskany; abandoned
39	L. Mis-Pocono	Elk River Gas Co.	Samuel Stephenson, et al, 1-18	0	437	540[2]	Big Injun gas well
40	M. Dev-Marcellus	Monickel Gas Co.	Stuart Lakes Inc., 1-M54	0	219	500[6]	Brown shale gas well
41	L. Mis-Pocono	Teavee Oil & Gas, Inc.	Ivan Davis, 1-15	0	0	0	Dry through Berea
42	L. Dev-Oriskany	West Virginia Gas Corp.	C. F. Hill, et al., 1-0-50	0	531	1,790	Oriskany gas well
43	L. Dev-Oriskany	United Fuel Gas Co.	S. D. Littlepage, 5-5058	0	0	0	Oriskany salt water
44	U. Dev-Chemung	Pittsburgh & W. Va. Gas Co.	Fannie R. Brightwell, 1-6119	0	?	?	Big Injun gas show; drilled through Warren; abandoned
45	U. Dev-Catskill	Cumberland & Allegheny Gas Co.	D. F. Harris, 1-302	0	479	420[4]	Gordon gas well
46	M. Dev-Genesee	Owens, Libbey-Owens Gas Dept.	Koonce & Zimmerman, 1-573	0	732	410[4]	Big Lime, Big Injun and Brown-shale gas well
47	M. Dev-Marcellus	Owens, Libbey-Owens Gas Dept.	Geo. P. Alderson, 1-618	0	24	?	Brown-shale gas show; abandoned
48	L. Mis-Pocono	Carnegie Natural Gas Co.	Mike Barr, 6-1565	221	0	0	Big Injun oil well
49	Sil-White Medina	Carnegie Natural Gas Co. and Glen Roberts	C. W. Cook, 1-33	0	0	0	Dry through White Clinton

[1] 1 hr. [2] 24 hr. [3] 33 hr. [4] 48 hr. [5] 68 hr. [6] 72 hr.
[7] 6 days. [8] 7 days. [9] 9 days. [10] 44 days.

16,000 acres, covering a north-south distance of 13 miles. Three salt-water wells apparently have set an eastern limit but the northern, western and southern boundaries are still conjectural. There is a good prospect that the pool may merge with the Elk-Poca Pool on the south, but at the end of the year there was an unproved stretch of about 4 miles between the two, with several wells drilling in the unproved belt.

In Kanawha County, various districts, 73 wells were completed through the Oriskany, resulting in 68 gas wells and five dry holes; and 45 uncompleted Oriskany tests were in progress at the end of the year (Table 3). Average initial open flow was about 2,500,000 cu. ft. per day and average initial rock pressure about 1200 lb. Of the total completions 62 were in Poca district. Two Oriskany wells, one in Elk and one in Poca district, were deepened to the White Clinton sand (Sil.) without finding production (Table 2).

The Elk-Poca gas pool, comprising parts of Elk, Poca and Union districts, Kanawha County; parts of Ripley and Washington districts, Jackson County; and the extreme eastern edge of Union district, Putnam County, was increased by about 20,000 proved acres during 1941, making its total extent about 80,000 acres. The Campbell-Davis Creek gas pool, comprising parts of Loudon and Malden districts, Kanawha County, and the Cooper Creek gas pool, including a small portion of Elk district, Kanawha County, were both inactive during 1941. The four pools, Buttermilk-Sandyville, Elk-Poca, Campbell-Davis Creek, and Cooper Creek, above discussed, make up the larger Charleston gas field and together contain about 107,000 acres of proved Oriskany sand gas production. Estimates of original Oriskany sand gas reserve in this field vary from 5,000,000 to 6,000,000 cu. ft. per acre, or a total of 535,000,000,000 to 642,000,000,000 cu. ft. Of this total perhaps 350,000,000,000 cu. ft. have already been recovered, leaving a large reserve, possibly 250,000,000,000 cu. ft., yet to be produced.

In Lewis County, Freemans Creek district, a successful Oriskany sand wildcat (Table 2) was completed by rotary drilling. The detailed log has not yet been released but trade journals report an initial flow of 474,000 cu. ft. and a rock pressure of 2300 lb. This well is one mile south of Freemansburg.

In Monongalia County, Morgan district, an Oriskany test was completed on Deckers Creek 6 miles southeast of Morgantown (Table 2), but was abandoned as dry. A volume of about 100,000 cu. ft. was found in the Huntersville chert (L. Dev.), but this gas was mostly flooded out by salt water, and the Oriskany was reported as dry.

In Roane County, Walton district, an Oriskany test 3 miles northwest of Cotton (Table 2) resulted in salt water.

In Tyler County, Meade district, an Oriskany test, Pearl Broadwater 1, by Benedum-Trees Oil Co., has been started one mile southwest of Falls Mills.

In Wood County, Steele district, an Oriskany test, I. B. Robinson et al., 1–34, by Glen W. Roberts, has been started on Tygart Creek a mile south of Saulsbury. In Tygart district a test through both the Oriskany and White Clinton (Sil.) on Sams Fork 2 miles southwest of Mineral Wells (Table 2) found no commercial production.

Operating Technology

No radical changes or improvements in operating technique are reported for the year. Secondary recovery of oil, mostly by gas, or combined gas-air, injection, continues to be used successfully in various old pools. Acidation of oil and gas wells in limestone formations has produced good results.

Pipe Lines, Compressor Stations and Markets

Various gas pipe lines of considerable size were built during the year and others of greater extent are projected. In Jackson County Columbian Carbon Co. extended its line from Goldtown northward 16 miles to Ripley. This line is variable in size but is reported as equivalent to a 12-in. diameter. In the same territory it is reported that Gas Transport, Inc., a subsidiary of Anchor Hocking Glass Corp., has under construction a 14 to 18-in. gas line from New Era, Jackson County, W. Va., northward past Parkersburg, Wood County, to Gravel Bank, Washington County, Ohio. From Gravel Bank the gas will be carried westward through lines of Ohio Fuel Gas Co. to Lancaster and other Ohio points. The estimated cost is reported as about $750,000, exclusive of compression equipment. In the same territory, also, Hope Natural Gas Co. is reported as having built 46 miles of 12-in. gas line from Ripely, northward to Waverly, Wood County. In Jackson and adjacent counties, also, West Virginia Gas Corporation has built 32 miles of 6-in., 3 miles of 8-in., and 3 miles of 10-in. gas transmission lines between unspecified points. These various lines will be required to handle Oriskany sand gas from the Charleston gas field.

The Owens, Libbey-Owens Gas Department has built 11 miles of 12-in. gas line between Brushton and Danville, Boone County, and 3 miles of 8-in. line in the vicinity of Sproul Tunnel, Kanawha County.

In Braxton County, Pittsburgh and West Virginia Gas Co. is reported as having built a 12-in. line from Servia northeastward 11 miles to the Engel farm. In Lewis County the same company is said to have built 6 miles of 16-in. line from Devaney northeastward to its Skin Creek compressor station; and from this compressor 11 miles of 6-in. line eastward to Lorentz, Upshur County.

Hope Natural Gas Co. has made surveys and applied for priorities to build 800 to 1000 miles of 20-in. line from the Monroe gas field of Louisiana northeastward to its Cornwell compressor station near Charles-

TABLE 3.—*Oriskany Sand Wells, Jackson and Kanawha Counties and Adjacent Part of Putnam County, W. Va.*

County and Magisterial District	Completed before 1941				Completed in 1941				Total Number of Completed Wells	Number of Wells Drilling or Unreported Jan. 1, 1942
	Gas Wells		Dry in Oriskany	Total Number of Wells	Gas Wells		Dry in Oriskany	Total Number of Wells		
	Number of Wells	Gas, M Cu. Ft.			Number of Wells	Gas M Cu. Ft.				
Jackson County:										
Grant	2	717	0	2	0	0	0	0	2	2
Ravenswood	4	9,269	2	6	28	166,675	1	29	35	25
Ripley	29	179,945	2	31	56	303,661	1	57	88	43
Washington	21	147,743	2	23	10	74,876	1	11	34	15
Total	56	337,674	6	62	94	545,212	3	97	159	85
Kanawha County:										
Big Sandy	0	0	1	1	0	0	0	0	1	0
Cabin Creek	0	0	3	3	0	0	0	0	3	0
Charleston	1	88	0	1	0	0	0	0	1	0
Elk	90	375,318	10	100	1	38	2	3	103	1
Jefferson	0	0	1	1	0	0	0	0	1	0
Loudon	8	3,788	5	13	0	0	0	0	13	0
Malden	35	73,181	5	40	0	0	0	0	40	0
Poca	266	2,171,833	2	268	61	162,489	1	62	330	43
Union	12	26,131	1	13	5	7,747	1	6	19	0
Washington	0	0	2	2	1	254	1	2	4	1
Total	412	2,650,339	30	442	68	170,528	5	73	515	45
Putnam County:										
Union	0	0	0	0	2	1,588	0	2	2	4
Grand total	468	2,988,013	36	504	164	717,328	8	172	676	134

ton, W. Va. An inquiry addressed to the company relative to the present status of this line brought the following reply: "No contract has been let for the building of this line and it is not certain whether it will be built, depending upon whether material will be available."

West Virginia Gas Corporation has built a 900-hp. compressor station, with equipment for dehydration and sulphur elimination to handle additional Oriskany sand gas in the Charleston gas field.

The price of oil has increased slightly during the year. Starting at $1.74 per barrel it rose, by small advances, to $2.34 on June 18. On Aug. 23, a further advance of $0.25 was posted but this advance was rescinded by order of the Office of Price Administration leaving the price $2.34 at the end of the year. Operators contend that a considerable price increase must be allowed before they can afford to drill for new oil.

The price or value of gas at the well mouth, according to the U. S. Bureau of Mines, stood at 12.7¢ per M cu. ft. in 1939, but decreased to 12.3¢ in 1940. Figures are not available for 1941, but the price did not change materially from that of 1940, although there was much better demand.

County Summary

Table 4 shows by counties the new development in West Virginia during 1941.

TABLE 4.—*Summary of New Development in West Virginia during* 1941

County	New Wells						Wells Drilled to Deeper Sands			
	Number of Wells	Oil Wells		Gas Wells		Dry Holes	Number of Wells	Production		Dry Holes
		Number of Wells	Bbl. per Day	Number of Wells	M Cu. Ft. per Day			Oil, Bbl. per Day	Gas, M Cu. Ft. per Day	
Boone	42	2	33	32	19,622	8	2	0	380	0
Braxton	41	0	0	19	12,039	22	5	0	10,620	0
Brooke	1	1	1	0	0	0	0	0	0	0
Cabell	19	1	25	16	3,319	2	1	0	73	0
Calhoun	73	24	452	46	30,029	3	1	0	225	0
Clay	34	7	42	20	16,815	7	1	0	338	0
Doddridge	6	1	12	5	723	0	7	0	541	2
Fayette	1	0	0	1	68	0	0	0	0	0
Gilmer	55	6	29	37	17,731	12	5	5	531	1
Hancock	9	9	25	0	0	0	0	0	0	0
Harrison	9	0	0	7	729	2	1	0	47	0
Jackson	101	2	55	94	545,198	5	2	0	14,517	0
Kanawha	98	9	1,144	82	203,137	7	11	0	9,502	2
Lewis	6	2	24	3	783	1	2	0	279	0
Lincoln	20	2	6	17	6,810	1	24	0	5,322	2
Logan	6	0	0	4	1,743	2	0	0	0	0
Marion	4	1	15	2	531	1	4	4	448	1
Marshall	7	0	0	5	790	2	1	0	260	0
Mason	2	0	0	1	450	1	0	0	0	0
Mingo	5	0	0	5	7,312	0	0	0	0	0
Monongalia	9	0	0	3	685	6	3	0	9,100	1
Nicholas	1	0	0	1	437	0	0	0	0	0
Pleasants	22	10	95	4	940	8	0	0	0	0
Preston	1	0	0	0	0	1	0	0	0	0
Putnam	53	1	45	46	37,559	6	3	0	2,543	0
Ritchie	72	14	197	33	13,517	25	8	0	746	3
Roane	19	6	132	4	1,771	9	0	0	0	0
Taylor	7	0	0	5	1,343	2	0	0	0	0
Tyler	8	4	18	2	2,017	2	0	0	0	0
Upshur	26	0	0	20	8,299	6	1	0	84	0
Wayne	39	2	6	33	6,998	4	1	0	31	0
Wetzel	18	2	227	9	7,711	7	1	0	254	0
Wirt	14	4	8	1	100	9	1	0	189	0
Wood	10	4	15	1	20	5	1	0	0	1
State total	838	114	2,606	558	949,226	166	86	9	56,030	13

This information is compiled from all available sources, including the trade journals, the West Virginia Department of Mines, the West Virginia Geological Survey, the special Plat Service afforded by Veleair C. Smith, Management, and from private reports.

The various reports do not altogether agree, but Table 4 attempts to reflect a careful history of every well that was completed in the state in 1941.

According to the Department of Mines, 1078 permits to drill were issued as compared to 782 in 1940. Of the 1078 permits issued, 709 wells had been reported to the Department as completed at the end of the year. The records of numerous other wells, available through weekly trade journals, etc., but not yet certified to the Department, largely account for the discrepancies of Table 4 as compared to Department figures.

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Petroleum Development in Argentina during 1941

By Mario L. Villa*

During the year 1941, there was another increase in the production of oil in Argentina, to which the fields in the Comodoro Rivadavia zone in the Territory of Chubut and those of the Provinces of Salta and Mendoza all contributed. The total production for this period reached 22,013,472 bbl., which represents an increase of 6.8 per cent over that of 20,609,538 bbl. in the preceding year.

This result is again attributable to the Government oil company, the Yacimientos Petroliferos Fiscales, which had a total production of 14,006,559 bbl. representing an increase of 1,531,904 bbl., or 12.3 per cent over that of the 12,474,655 bbl. of the year before. The other companies

Table 1.—*Oil and Gas Production in Argentina*

Line Number	Field, *Territory or Province*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[b]	To End of 1940	During 1941
	Comodoro Rivadavia, *Chubut*					
1	Zone A	34	11,684	990	108,238,358	4,420,687
2	Zone B	17	12,138	690	61,122,314	10,290,679
3	Zone C	25	2,930	250	18,191,101	1,005,444
4	Zone D	8			24,361	
	Plaza Huincul, *Neuquén*					
5	Zone 1	23	220	120	1,688,642	41,901
6	Zone 2	15	1,588	370	5,032,966	749,713
7	Zone 3	17	590	250	9,860,028	258,716
8	Zone 4	7	40		44,678	
9	Zone 5 (Loma Negra)	2	25			1,871
10	Zone 6 (Portezuelo)	1	50			2,010
11	Zone 7 (Challacó)	1	50			12,222
12	Zone 8 (Senillosa)	2				
	Province of Salta					
13	Zone Tartagal	15	986		5,262,225	614,477
14	Zone San Pedro	13	370		10,552,557	696,139
15	Zone Aguas Blancas	15	50		992,253	76,658
16	Zone Río Pescado	8	105		261,182	495,608
	Province of Mendoza					
17	Zone Cacheuta	10	360		408,137	54,167
18	Zone Tupungato	8	565		3,161,374	2,930,974
19	Zone El Sosneado	16	50		261,079	3,213
20	Zone Ranquilcó	3			1,950	
21	Zone Lunlunta and Barrancas	3	50		140,545	361,179
22	Total		31,851	2,670	225,243,750	22,015,658

[b] Footnotes to column heads and explanation of symbols are given on page 250.

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* Gerente General, Yacimientos Petroliferos Fiscales, Buenos Aires, Argentina.

showed a decrease of 127,593 bbl., or 1.6 per cent, their production being 8,006,912 bbl. as compared with 8,134,882 bbl. for the year 1940.

Of the total of 22,013,472 bbl. produced in Argentina in 1941, the Comodoro Rivadavia zone contributed 15,716,811 bbl., the Plaza Huincul zone 1,071,237 bbl., the Province of Salta 3,344,211 bbl., and the Province of Mendoza 3,344,211 barrels.

Table 3 shows the production by companies in the Comodoro Rivadavia zone for 1940 and 1941, and the change for the latter year. The net increase of 740,529 bbl., or 4.9 per cent, in this zone was caused by additional development within the proven areas and by the addition of El Tordillo to the list of producing fields in the latter part of the year.

Three wildcat wells were drilled by the Y.P.F. in the Territory of Santa Cruz. Well 0-2, approximately 35 km. to the east-northeast of the town of Las Heras, was drilled to a total depth of 1566 meters, and abandoned as a dry hole. It entered the hard tuffs of the Chubutiano, which lie below the productive horizons of the Comodoro Rivadavia zone. Well 0-8, in a faulted zone 30 km. south-southwest of the town of Comodoro Rivadavia, was drilled to 1578 m. and abandoned without the finding of any productive horizons. Well 0-9, a short distance from the coast and 130 km. south of Comodoro Rivadavia, found the top of the flows and tuffs of

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells						Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Repressuring Operation[d]	Character of Oil	
	To End 1940	During 1941	Completed to End of 1940	During 1941		End of 1941			Number of Wells		Initial	Avg. at End of 1941		Gravity A.P.I. at 60°F., Weighted Average	Sulphur, Per Cent
				Completed	Abandoned	Temporarily Shut down	Producing Oil[c]	Producing Gas[c]	Flowing	Artificial Lift					
1	190,731	7,422	2,560	89	62	231	1,824	21	12		x	134 520	SR	207	
2	39,811	5,597	940	155	21	70	819	25	5		x	397 1,123	PM	242	
3	11,446	641	785	57	58	124	387	34			285	x	SR	190	
4			4			4		2			x			231	
5	1,968	109	84	1	1	11	48	2			x	x		307	
6	10,171	2,847	180	14	3	32	129	4	25		1,110	612	SR	354	
7	9,969	266	213	1	5	46	98	6				x	SR	336	
8	1,624		5	1	1	2							SR	384	
9			1	2	1	2					1,482	x		292	
10				3	1		2				x	x		428	
11				1			1				1,078	x		240	
12				3	1			2			x	x			
13	7,735	1,619	177	13	2	28	131		10	22	783	576	PM	454	
14	10,641	1,100	45				25		25		726	512		445	
15			6	1		1	5		3		413	328		479	
16	179	598	14	6	1	1	14		11	3	1,926	1,396	PM	499	
17	40	29	44	1		3	25		1		x	x		316	
18	788	579	21	11	4	7	20		17		3,329	2,726		333	
19			14								x	x		129	
20			6			2					x	x		135	
21	11	52	5	5	1		6		6		4,265	4,090		292	
22	285,114	20,859	5,104	364	162	564	3,534	96	115	25					

the Serie Porfirítica at 300 m., and was abandoned in that series at 407 m. The Chubutiano was completely missing.

Farther south, the Cía. Ultramar drilled its Piedra Clavada No. 1 north of the Río Shehuen and 200 km. west of the town of Santa Cruz, to a depth of 1450 m. A large flow of gas was found in the Lower Cretaceous from 803 to 813 m. This well drilled through the flows and tuffs of the Serie Porfirítica, finding metamorphosed sediments of probable Paleozoic age from 1290 to 1450 m., at which depth it was abandoned.

In the Territory of Chubut, the Y.P.F. drilled a number of wells to extend the productive limits of the known pools, and also several wildcats in the search for new fields. The most important of the latter were wells S-145 and V-1, the first 15 km. south-southwest of El Trébol pool and the second 22 km. north of that pool, neither of which found oil in any of the horizons productive in the other fields.

The oil production in the Plaza Huincul zone, in the Territory of Neuquén, showed a net decrease of 204,577 bbl. or 16 per cent of the production of 1940 (Table 4).

Of the wildcat wells drilled by the Y.P.F. in the Territory of Neuquén, three were productive and two were abandoned as dry holes.

The well NCN-1, 16 km. north-northeast of Zapala, was drilled to a depth of 1765 m., reaching the upper part of the sandstones of the Callovian. Shows of oil were found

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1941	
	Name	Age[e]	Character[f]	Porosity[g]	Depth, Avg. Ft.		Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
					Top Prod. Zone	Bottoms Prod. Wells				
1	Glauconítico y Chubutiano	CreU	S	28	1,640 2,300	1,800 3,940	30	AF	Chubutiano	7,751
2		CreU	S	25	2,620 4,920	2,690 6,400	36	AF	Chubutiano	6,389
3		CreU	S	28	1,640	2,130	13	AF	Chubutiano	3,660
4	Chubutiano	CreU	S	20	2,890	2,920	28	A	Chubutiano	6,615
5	Dogger	Jur	S	Por	1,870	1,990	39	MU	Liásico	3,011
6		Jur	S	20–29	2,480	2,722	36	MU	Liásico	5.320
7		Jur	S	Por	2,686	2,878	56	MU	Liásico	4,202
8		Jur	S	18	3,346	3,367	7	MU	Liásico	5,038
9		Jur	S	Por	3,346	3,476	66		Dogger	3,578
10		Jur	S	Por	2,702	2,811	28		Dogger	3,610
11		Jur	S	Por	3,214	3,280	66		Dogger	3,267
12	Estratos con dinosaurios	CreU	S						Dogger	5,888
13	Arenisca superiores Calcareo y Gondwana	Cre Per	S-LS	12–20	2,139 2,783	2,214 3,093	33	A	Gondwana	6,035
14	Gondwana y Devónico	Per-Dev	S	Por	2,899	2,995	30	A	Devónico	3,920
15	Areniscas superiores y Gondwana	Cre Per	S	12–22	4,592	4,920	40	A	Gondwana	5,182
16	Terciario Subandino	Ter	S	Por	4,175	4,376	103	A	Terciario	6,006
17	Victor Cacheuta y Potrerillos	Tri	S	Por	1,940	3,080	13	MUP AF	Serie porfirítica	4,303
18	La Pilona y	Ter	HS	Por	1,740 5,870	1,400 6,310	69	A	Victor	7,226
19	Victor	Tri	S	Por	544	551		MI		
20	Neocomiano	Ter CreL CreL	LS	Por	939	1,220	30	A	Serie porfirítica	3,599
21	Potrerillos	Tri	S	Por	7,721	7,892	45	A	Potrerillos	9,479
22										

at a number of horizons, but all failed to produce because of their low permeability.

Well NM-1, 50 km. northwest of Plaza Huincul and 2 km. west of the shallower well drilled by the Standard Oil Co. some years before, reached a depth of 2782 m., making it the second deepest well in Argentina. After drilling a thick section of the Lower Cretaceous, it was abandoned in beds believed to be of Jurassic age, although this correlation is not certain.

NL-3, 15 km. west of Plaza Huincul, was drilled on the same structure as wells NL-1 and NL-2, drilled the preceding year, but

TABLE 2.—*Summary of Drilling Operations in Argentina*

Important Wildcats Drilled in 1941

	Province or Territory	Location	Well	Total Depth, Meters	Surface Formation
1	Chubut	C. Rivadavia	S-145	2.047	Patagoniano
2	Chubut	C. Rivadavia	V-1	1.295	Patagoniano
3	Santa Cruz	Las Heras	Ó-2	1.566	Patagoniano
4	Santa Cruz	C. Rivadavia (Sud)	Ó-8	1.578	Patagoniano
5	Santa Cruz	Puerto Mazarredo	Ó-9	407	Patagoniano
6	Santa Cruz	Mata Amarilla	PC-1	1.450	Tertiary
7	Neuquén	Covunco Centro	NCN-1	1.765	Lower Cretaceous
8	Neuquén	Paso de los Indios	NM-1	2.782	Upper Cretaceous
9	Neuquén	Portezuelos	NJ-1	1.100	Upper Cretaceous
10	Neuquén	Challacó	NA-4	996	Upper Cretaceous
11	Salta	Río Pescado	AM-2	1.292	Tertiary
12	Jujuy	San Pedro de Jujuy	S-2	1.351	Tertiary
13	Mendoza	Ranquil-Có	PP-1	948	Upper Cretaceous
14	Mendoza	Tupungato Refugio	TR-1	2.250	Pliocene
15	Mendoza	Lunlunta Carrizal	LC-1	2.896	Pliocene

Important Wildcats Drilled in 1941

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U.S. Barrels	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Chubutiano	Y. P. F.						Dry hole
2	Chubutiano	Y. P. F.						Dry hole
3	Chubutiano	Y. P. F.						Dry hole
4	Chubutiano	Y. P. F.						Dry hole
5	Serie Porfirítica	Y. P. F.						Dry hole
6	Triassic	Ultramar		12 with 93% CO_2		940		Abandoned
7	Jurassic	Y. P. F.						Dry hole
8	Jurassic	Y. P. F.						Dry hole
9	Dogger	Y. P. F.	38					
10	Dogger	Y. P. F.	1,071					
11	Tertiary	Y. P. F.						Dry hole
12	Silurian	Ultramar						Abandoned
13	Upper Jurassic	Y. P. F.	10	21		213		Suspended
14	Triassic	Y. P. F.	126					
15	Triassic	Y. P. F.						Not completely tested

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1941	36	16
Number of oil wells completed during 1941	263	38
Number of gas wells completed during 1941	8	3
Number of dry holes completed during 1941	30	22

2½ km. east of them. It obtained an initial production of 22 cu. m. of oil in the same horizon that produces at Plaza Huincul, but it has not been produced because of its high gas-oil ratio.

TABLE 3.—*Production in Comodoro Rivadavia Zone*

BARRELS

Company	In 1940	In 1941	Difference
Y. P. Fiscales	8,469,730	9,137,697	+667,967
Ferrocarrilera	947,500	959,929	+ 12,429
Industrial y Comercial	234,743	254,532	+ 19,789
Diadema	4,203,833	4,235,227	+ 31,394
Astra	898,833	923,234	+ 25,116
Solano	222,358	206,192	− 16,166
Total	14,976,282	15,716,811	+740,529

In the Portezuelo zone, 30 km. west-northwest of Plaza Huincul, well NJ-1 was drilled on a seismograph structure. It found oil, gas and water at a depth of 832 m. in beds that are probably of the same stratigraphic position as the producing horizons of Plaza Huincul. Drilling was continued to 1100 m., with the discovery of three important gas sands.

TABLE 4.—*Production in Plaza Huincul Zone*

BARRELS

Company	In 1940	In 1941	Difference
Y. P. Fiscales	675,414	549,827	−125,587
Standard Oil Co	197,437	177,114	− 20,323
Compañía "La República"	402,963	344,296	− 58,667
Total	1,275,814	1,071,237	−204,577

On the basis of seismograph studies, well NA-4 was drilled 5 km. southeast of the station of Challacó, 25 km. east-southeast of Plaza Huincul, resulting in the most important discovery in the Plaza Huincul zone. The producing sand was found at 984 m., and after a penetration of 12 m. gave an initial production of 170 cu. meters.

The exploration of the Senillosa area was continued with the drilling of NS-4 to a depth of 1795 m. Good shows of oil were found in the Lower Cretaceous, but nothing was found in the Dogger.

The production of oil in the Province of Salta (Table 5) during the year of 1941 amounted to 1,881,213 bbl., which represents an increase of 35,236 bbl. (1.9 per cent) over that of the preceding year.

TABLE 5.—*Production in Province of Salta*

BARRELS

Company	In 1940	In 1941	Difference
Y. P. Fiscales	818,046	978,038	+159,992
Standard Oil Co	1,027,931	903,175	−124,756
Total	1,845,977	1,881,213	+ 35,136

In that Province, the work of the Government company, the Y.P.F., resulted in important extensions of the productive areas of the Tranquitas and Río Pescado fields. Well AM-4, 3 km. north of the Río Pescado field, was drilled to a depth of 1292 m., and abandoned as a dry hole.

The Cía. Ultramar drilled its Saladillo No. 2, a short distance west of the town of San Pedro in the Province of Jujuy, and abandoned it after reaching a depth of 1351 m. in beds of Silurian age.

In the Province of Mendoza during the year 1941, another considerable increase in production was obtained over that of the preceding year. The total was 3,344,211 bbl., an increase of 44.4 per cent over the 2,315,947 bbl. of 1940. It should be noted that virtually all of the production was obtained from the fields of the Y.P.F., as the 3210 bbl. of the Cía. Atuel came from tests made near the end of the year on wells that had been shut down for several years.

The Government company drilled wells in the Tupungato, Lunlunta and Barrancas fields during 1941, which extended their productive limits.

Drilling was completed on the exploration well LC-1, on the Carrizal structure, 12 km. south-southeast of L-3, the discovery well of the Barrancas field. It reached a depth of 2896 m., or the deepest in Argentina. No oil was found in the horizons that are productive in Lunlunta or Barrancas, but shows of oil were noted at higher levels, which have not yet been tested.

The exploration well TR-1 on the Refugio structure, 3 km. northwest of the center of the Tupungato field, was drilled to a depth of 2250 m., finding oil in the beds that are productive at Tupungato, with an initial production of 15 cu. meters.

In the south of the Province of Mendoza, well PP-1 was drilled on the surface structure of Pampa Palauco. Dry gas was found in various beds of the Estratos con Dinosaurios (Upper Cretaceous) and Lower Cretaceous, the largest volume recorded being 620,000 cu. m. per day and the highest pressure 213 lb. per sq. in. Numerous shows of oil were noted, and some beds of the upper part of the Jurassic produced small quantities of a very heavy oil.

Drilling and Producing Activities in Brazil

By J. E. Brantly,* Member A.I.M.E.

In October 1939, a drilling program was commenced on the Atlantic seaboard of Brazil, with three steam rotary rigs of medium capacity. One of these was assigned to the State of Alagôas and the other two to the State of Bahia. During the remaining few months of 1939 and during the year 1940, some eight wells were drilled, two in Alagôas and six in Bahia. Two small producers were found in the latter state.

In early 1941 three medium-weight Diesel rigs were added to the equipment, thus permitting the drilling of some 15 wells during the year 1941.

The two small producers found in 1940 in the State of Bahia were near the city of São Salvador. In 1941 three additional small wells were brought in, in the same area, and a further producer on an isolated structure some 75 km. to the northwest of this production. No commercial production has been found in the State of Alagôas. Approximately 26 wells have been drilled or are drilling, six of which are producers—five in one area and one in another.

The program for 1942 calls for the development of the two areas in which wells have been found and also the drilling of several wildcat structures located either by geophysics or surface geology.

All production in the area of the several producing wells is somewhat less than 2000 ft. and in the other area about 3800 ft. The area of the several wells is known as the Lobato field, and is practically within the city limits of São Salvador. The area 75 km. northwest of the city will be known as the Candeias field.

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Petroleum Developments in Canada in 1941

By G. S. Hume*

The largest development program in the history of Alberta was undertaken in 1941 in an effort to increase oil production. The drilling record is as follows:

Field	Drilling, Ft.	
	In 1940	In 1941
Turner Valley	296,832	376,676
Other oil fields	23,448	51,824
Gas development	1,045	16,123
Exploration	48,779	46,176
Total	370,104	491,339

In Alberta there was the largest exploratory campaign for oil in the history of the Province, although drilling of wildcat wells was somewhat less than in the previous year. A great deal of geophysical work was done. This included three gravimetric and five seismic parties as well as a number of geological survey parties by the major oil companies and by the Geological Survey of Canada. Seismic work was done by one party in southern Saskatchewan.

Table 1.—*Production*[a] *of Petroleum in Canada*
Barrels

Province	1940	1941[b]
New Brunswick	22,167	22,332
Ontario	187,644	160,000
Alberta	8,362,203	9,928,162
Northwest Territories	18,633	14,119
Saskatchewan	331	
Total	8,590,978	10,124,613
Value	$11,160,213	$14,217,424

[a] Information from the Dominion Bureau of Statistics, Ottawa, is based on sales and hence does not exactly correspond with actual production.
[b] Preliminary figures.

The production of petroleum in Canada is shown in Table 1. About 98 per cent of the total production comes from Alberta and the yield of the various fields is shown in Table 2.

Table 2.—*Production*[a] *of Petroleum in Alberta*
Barrels

Turner Valley	1940	1941
Palaeozoic limestone:		
Oil wells	8,142,626	9,504,111
Gas wells	30,390	27,096
Shallow oil wells (Cretaceous)	7,309	6,014
Natural gasoline	274,172	293,122
Total Turner Valley	8,454,497	9,830,343

[a] Information from F. K. Beach, Petroleum and Natural Gas Conservation Board, Alberta.

Field	Number of Producing Wells	1940	Number of Producing Wells	1941
Red Coulee	7	12,177	7	11,626
Wainwright	4	7,527	6	11,733
Miscellaneous				
Dina	2	4,746	2	2,894
Lloydminster	2	1,648	1	416
Vermilion	3	10,817	8	22,051
Del Bonita	2	3,444	2	4,393
Taber	0		1	5,600
Princess	0		2	19,587
Moose Mountain	1	351	0	
Turner Valley		8,454,497		9,830,343
Total for Alberta		8,495,207		9,908,643

Turner Valley

The greatest developments in Turner Valley have been in the north end. In 1941 about two miles of new productive area was proved by drilling, extending the field to a length of 20 miles. The wells at the

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TABLE 3.—*Production*[a] *of Natural Gas in Canada*

THOUSANDS OF CUBIC FEET

Province	1940	1941[b]
New Brunswick	616,041	610,393
Ontario	13,053,403	12,131,895
Manitoba	600	
Saskatchewan	100,773	105,328
Alberta	27,459,808	26,365,770
Northwest Territories	1,500	
Total	41,232,125	39,213,386
Value	$13,000,593	$12,356,067

[a] Information from Dominion Bureau of Statistics, Ottawa.

[b] Preliminary.

north end of the field are very productive in comparison with moderately productive wells at the south end and less productive wells in the central area. In part of the central area the porosity has been mainly confined to one zone in the upper part of the Paleozoic limestone, whereas at both the south and north ends of the field there are two porous zones. In parts of the central zone even the one porous zone is comparatively tight; some nonproductive wells have been drilled within what would ordinarily be considered proven territory and some other wells obtained only small yields by intensive acidization. The large productive capacity of the wells at the north end of the field may be partly due to fracturing of the limestone reservoir rock as well as to high porosity. A few small faults have been encountered in the limestone, which mostly is free from faults in other parts of the field. The limits of the field are defined on the east by a major thrust fault, which cuts off the gas cap; on the south by the southward plunging end and on the west by the water line at an elevation of 4100 to 4500 ft. below sea level. The water-oil line is at a lower elevation in the upper porous zone than it is in the lower porous zone and as a consequence production of oil on the west flank of the structure is secured farther west—i.e., down the dip—in the upper porous zone than in the lower porous zone. The north end of the field is not yet defined, but owing to the large yields in the more northerly wells an extensive campaign of wildcat drilling along the assumed strike of the field has been undertaken for 12 miles north of the most northerly producing well. It is thought that the limestone fault block that constitutes the Turner Valley field continues northwestward through this area where drilling is being done. The success of the wells, however, will be dependent on the depth at which the limestone can be reached. The most northerly productive well, Atlas British Dominion No. 2 (completed Feb. 1, 1942) reached the top of the Paleozoic limestone at an elevation of 4138 ft. below sea level, presumably less than a couple of hundred feet above the water-oil line in the lower porous zone. In the northerly part of the north end of the productive area, the north plunge is very slight, if any, but 5 miles northwest the surface northwest plunge is very marked. The width of the field in this north end is not yet precisely determined. The oil-water line on the west is approximately known but on the east the position of the fault, which farther southeast cuts off the east side of the field, has not yet been determined. The present known width in the north end is about ½ mile across the strike.

OTHER FOOTHILLS AREAS

Grease Creek Area.—A second well is being drilled in the Grease Creek area, which is about midway between the Bow and Red Deer Rivers. The first well in this area was abandoned on account of mechanical difficulties, at a depth of 7011 ft. The structure is a sharply folded and faulted anticline and the prospects for oil and gas are dependent on whether or not the Paleozoic limestone is included in the fold above a major thrust fault.

Clearwater Area.—The Clearwater anticline lies northwest of Grease Creek and is a Paleozoic limestone outlier in which drilling commenced in the Mississippian and continued into the Devonian limestones. In the first well shows of oil were encountered and the well was abandoned at a depth of 3052 ft. Some shows of oil and gas were also encountered in the second well between 1300 and 1400 ft. in depth. The well was continued to a depth of 3004 feet.

Ram River Area.—This is the north continuation of the Clearwater limestone outlier. A first well on the structure encountered a major fault at a depth of approximately 1200 ft. and passed from Devonian into Upper Cretaceous strata. A second well farther west is now drilling and at the end of 1941 had reached a depth of 3356 ft., with some oil shows reported.

Moose Mountain Area.—Moose Mountain is a limestone outlier about 45 miles west of Calgary. A test in this area was completed by McColl-Frontenac Oil Co. in 1941, at a depth of 5200 ft. The well commenced near the base of the Mississippian and passed through the Devonian into Cambrian strata. Although shows of gas occurred, the well was noncommercial. Two wells in the central part of Moose Mountain previously drilled to much shallower depths gave oil and gas, and oil from the Devonian was produced from one of these for some time.

Maxmont Well, Lundbreck Area.—This well is in the southern foothills northwest of Lundbreck, in the Crow's Nest Pass area. The well has been drilled with cable tools, and at the end of the year had reached a depth of 9080 ft., a record for cable-tool drilling in Canada. Some shows of oil have been encountered.

PLAINS AREAS

Princess.—The Princess, or Steveville, area is 100 miles east of Calgary. Operations including geological and geophysical surveys and drilling have been continued for some years by various companies but drilling in 1941 was done mainly by the Standard Oil Co. of B.C. A number of wells have been found to contain gas and several have obtained substantial shows of oil, but in only two,—namely, Princess Nos. 2 and 6—have commercial yields of oil been found. In Princess No. 2 well the oil occurs in the upper part of the Paleozoic limestone, whereas in Princess No. 6 well, which was completed in December 1941, it is in the Sunburst sand at the base of the Lower Cretaceous.

Brooks-Tilley Area.—To the southwest of the Princess area, the Northwest Company commenced a well near Brooks in October 1941. The well was completed early in 1942 without production. The operations are to be continued in the Brooks-Tilley area in 1942. The locations

TABLE 4.—*Oil and Gas Production in Turner Valley, Alberta, Canada*[1]

Line Number	Field	Year of Discovery	Area Proved (Drilled), Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Completed to End of 1941	Number of Oil and/or Gas Wells				
										During 1941		End of 1941		
			Oil	Gas[b]	To End of 1941	During 1941	To End of 1941	During 1941		Completed	Abandoned	Temporarily Shut Down	Producing Oil[c]	Capable of Producing Gas[c]
1	Turner Valley.........	1924	7,000	10,000	45,906,223	9,830,343	1,175,363	53,843	295	43[2]	0		175	97

are being made from the results of extensive seismic work done in 1941.

Blood Indian Reserve.—In 1941 the Northwest Company completed one well on the Blood Indian Reserve, southwest of Lethbridge, and drilled a second. The first well, completed at 8282 ft., tested both the Mississippian and Devonian, whereas the second well reached the top of the Mississippian limestone at a depth of 6030 ft. and was completed at 6074 ft. Both wells encountered water with only shows of gas and oil. The structure on the Blood Indian Reserve was determined by seismograph. The structure tested by No. 1 well was apparently the continuation of the Del Bonita-Spring Coulee trend on the northward-plunging Sweet Grass arch. It was shown by the seismic work to be separated from the Spring Coulee anticline by a saddle at least 150 ft. deep. The fact that it did not yield oil or gas was very disappointing, since so many wells in other parts of southern Alberta have given such good shows where the structure is known to have been much less favorable.

Borradaile Field, Vermilion Area.—The Vermilion area is 130 miles east of Edmonton. A number of wells have been drilled on what is known as the Battleview anticline and both gas and oil have been found. The most extensive development has been at Borradaile, about 6 miles east of Vermilion. The first well in this area, finished at 1858 ft., was placed on the pump on May 13, 1940. To the end of 1941 it produced 16,267 bbl. of oil of 14° to 15° A.P.I. The oil is in a sand in Lower Cretaceous beds. To date there have been 16 wells drilled in this field, of which seven were drilled in 1941. Eight wells are now being pumped. The oil is treated to remove silt and a small amount of emulsion, and is being shipped for fuel for the Canadian National Railroad.

Pouce Coupe - Peace River Area.—The Guardian well at Pouce Coupe was continued in 1941 and reached a depth of 6896 ft. About 2000 ft. of Triassic beds were penetrated and the well is now in Paleozoic strata. As previously reported, shows of oil occurred in the Triassic. About 80 miles to the west of this well, Pine River No. 1 well, at the mouth of Commotion Creek, in the Foothills belt, has been continued to a depth of more than 5500 ft. with the well still in Lower Cretaceous rocks.

Athabaska Bituminous Sands.—The plant of Abasand on Horse Creek, near Mc-

TABLE 4.—(*Continued*)

Line Number	Oil-production Methods, End of 1941		Reservoir Pressure, Lb. per Sq. In.		Character of Oil	Producing Formation								Deepest Zone Tested to 1941	
	Number of Wells									Depth, Avg. Ft.					
	Flowing	Artificial Lift	Initial Gas Area	At End of 1941	Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Top of Producing Zone	Bottom of Producing Zone	Net Thickness, Avg. Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	174	1	2000	[3]	42	Rundle (Madison)	Mis	L	Por[4]	7,351	8,002	470	A[5]	Mis	5,870[6]

[1] Information from F. K. Beach, Conservation Board, Alberta.

[2] In addition two wells were drilled and abandoned on the west edge of the field.

[3] Variable in different parts of the field.

[4] Combined thickness of two porous zones 120 to 150 feet.

[5] Structure anticlinal on east edge of a faultblock.

[6] McLeod No. 4 well faulted to Upper Cretaceous below Mississippian beds.

Murray, 300 miles north of Edmonton, was in commercial production in 1941. For several years experiments have been carried on under the supervision of Max W. Ball, and although many difficulties have been met, those connected with the mining of the bituminous sand and the extraction of the bitumen from it have been successfully overcome. From May until October, 21,713 tons of sand were mined, from which 19,519 bbl. of bitumen were extracted. This bitumen yielded 1142 bbl. of gasoline and 4190 bbl. of Diesel and burner oil, which was used mainly by the mine of Consolidated Mining and Smelting Co. on Lake Athabaska. In November, the operations at Abasand were interrupted by a fire in the extraction plant but the loss is being replaced by new equipment and it is probable the plant will again be in operation in 1942.

ONTARIO

Explorations have continued in the southwestern peninsula of Ontario, mainly in the search for natural gas. Some geophysical work was undertaken in 1941. Drilling was continued in the known gas fields, particularly in the Malahide field of Elgin County, and although new exploratory wells did not open any new fields, individual wells were successful in discovering locally high areas on the top of the Guelph (Silurian) formation, in the upper part of which a productive gas zone occurs.

Petroleum Developments in Mexico during 1941

By Thomas R. Armstrong*

Total crude oil production in Mexico in the year 1941 is estimated at approximately 41,000,000 bbl.; a daily average of 112,700 bbl. and a decrease of about 5 per cent as compared with the daily average of 120,000 bbl. produced in the year 1940, and nearly 11 per cent decrease as com-

Table 1.—*Oil and Gas Production in the Republic of Mexico*

Line Number	District	Year of Discovery	Area Proved, Acres	Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	Number of Oil and/or Gas Wells					
			Oil	To End of 1941[1]	During 1941[1]	To End of 1941	Completed to End of 1941	During 1941: Completed	During 1941: Abandoned	End of 1941: Temporarily Shut Down	End of 1941: Producing Oil[c]	End of 1941: Producing Gas[c]
1	Northern	1901	350,000	757,867,000	5,658,000	y	1,622	3	y	150	509	
2	Southern	1910	21,500	1,032,850,000	5,107,000	y	586	0	y	94	168	
3	Poza Rica	1930	14,500	148,844,000	24,406,000	y	40	3	y	2	34	
4	Isthmus of Tehuantepec	1909	10,000y	117,291,000	5,956,000	y	366	7	y	35y	190	
5	Northern Mexico	1931	5,000y		0	y	16	1	y			16y
6			401,000	2,056,852,000	41,127,000		2,630	14		281	901	16y

[c] Footnotes to column heads and explanation of symbols are given on page 250.
[1] November and December estimated.

Line Number	Oil-production Methods, End of 1941: Number of Wells		Reservoir Pressure, Lb. per Sq. In.	Repressuring Operation[d]	Character of Oil	Producing Formation				
	Flowing	Artificial Lift	Initial		Gravity A.P.I. at 60°F., Weighted Average	Name	Age[e]	Character[f]	Porosity[g]	Structure[h]
1	509	0	x		11–14	Tamasopa limestone	Cre M	L		AF[2]
2	168	0	x		20–24	El Abra limestone	Cre M	L	Car y	AF[3]
3	34	0	x		30–32	Tam-Abra limestone	Cre M	L	Por y	A[4]
4	10y	180y	x		23–33	Sands	Olig-Mio	S	Por y	DS[5]
5	16y	0	x			Sands	Olig-Mio	S	Por y	A
6	737	180								

[2] Producing from fractures in nonporous limestone.
[3] Producing from porous (reef phase) limestone.
[4] Producing from porous zone 500 ft. ± below top of Mid-Cretaceous.
[5] Producing from chiefly Miocene with some Oligocene sands.

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* Standard Oil Company of New Jersey, New York, N. Y.

TABLE 2.—*Estimated Daily Average Mexican Production*

U. S. BARRELS OF 42 GALLONS

Area	1937	1939	1940	1941	Total to End of 1941
Northern	26,867	15,112	16,907	15,501	757,867,000
Southern	22,718	12,672	10,301	13,992	1,032,850,000
Poza Rica	51,053	72,115	77,481	66,866	148,844,000
Isthmus	27,281	17,304	15,293	16,318	117,291,000
Total daily average	127,919	117,203	119,982	112,677	
Total	46,690,000	42,779,000	43,914,000	41,127,000	2,056,852,000

TABLE 3.—*Exports of Crude and Products from Mexico*

U. S. BARRELS OF 42 GALLONS

Classification	1939	1940	1941[a]
Panuco crude	4,227,000	2,417,000	1,280,000
Southern crude	241,000	1,124,000	1,760,000
Poza Rica crude	7,071,000	11,073,000	5,650,000
Isthmus crude	803,000	0	0
Fuel oil	2,089,000	1,340,000	3,330,000
Gas oil	1,626,000	2,817,000	2,120,000
Gasoline	1,488,000	455,000	1,280,000
Kerosene	42,000	269,000	130,000
Lubricants	2,000	1,000	0
Asphalt	481,000	516,000	390,000
Total	18,070,000	20,012,000	15,940,000
Bunkers: fuel oil	833,000	505,000	310,000
Gas oil	157,000	37,000	0

DESTINATION OF EXPORTS, PERCENTAGE OF TOTAL

Destination	1939	1940	1941[a]
United States	30.2	78.6	87.5
Latin America	2.2	1.4	12.3
Europe	64.0	15.3	0
Japan	1.0	3.8	0
Others	2.6	0.9	0.2
Total	100.0	100.0	100.0

FIGURES COMPILED FROM THE OFFICIAL *Revista de Estadistica* FOR DECEMBER 1941

Classification	January–July 1940			January–July 1941		
	Barrels Exported	Value in Pesos	Avg.	Barrels Exported	Value in Pesos	Avg.
Light crude	6,852,000	29,414,000	4.29	3,969,000	12,509,000	3.15
Heavy crude	1,598,000	5,500,000	3.44	561,000	1,606,000	2.86
Fuel oil	1,431,000	6,493,000	4.54	2,331,000	6,121,000	2.63
Gas oil	1,107,000	10,127,000	9.15	353,000	1,700,000	4.82
Gasoline	159,000	1,615,000	10.16	517,000	2,832,000	5.48
Kerosene	522,000	3,624,000	6.94	1,078,000	6,068,000	5.63
Asphalt	367,000	3,020,000	8.23	165,000	962,000	5.83
Total	12,036,000	59,793,000	4.97	8,974,000	31,798,000	3.54
Average price in U. S. Currency			$0.863			$0.727

[a] Estimated.

pared with the year 1937. A comparison of daily average production is given in Table 2.

DRILLING

During the past year, 28 wells were called completions in Mexico, of which six were considered abandoned because there had been no activity for two or three years. Fourteen producers were completed, three in the Northern district, three in Poza Rica, and eight in the Isthmus of Tehuantepec. At the end of 1941, six wells were reported drilling, nine were classed as "operations temporarily suspended," and there were nine active locations.

REFINING

Detailed figures on refining activities are not available. The effects of not having made major repairs in four years of operation, coupled with the fact that the plants have been under the supervision of comparatively nontechnical operators, are reflected in the present status of refining operations. Refined gasoline output under private administration in 1937 amounted to 7,235,000 bbl., of which 4,400,000 bbl. were exported. In 1941, although there was a sufficient supply of crude oil, refined gasoline output is not expected to exceed 4,100,000 bbl., and it was necessary to import about 500,000 bbl. to meet domestic consumption.

With constantly decreasing output and increasing demand, it is more than probable that Mexico will be forced to import about 1,000,000 bbl. of refined gasoline during 1942.

EXPORTS

Exports suffered a 20 per cent decline over 1940. The total of almost 16,000,000 bbl., consisting of approximately 50 per cent crude and 50 per cent refined products, should compare with the 1937 figure of 24,500,000 bbl., of which about 70 per cent was refined products. Table 3 shows the exports of crude and petroleum products from Mexico for 3 years. The 1941 data are estimated, since figures have not been published for the complete year.

In a review of the economic situation of Mexico in the December 1941 monthly bulletin of the Banco Nacional de Mexico, it is pointed out that the country will end 1941 with an unfavorable balance of trade for the first time in a great number of years. The decline in petroleum exports both in volume and value in 1941 partially explains this reversal in trade trends. In 1937 petroleum exports accounted for nearly 20 per cent of the total value of Mexican exports. In 1940, it accounted for less than 9 per cent.

GENERAL

Mexico's petroleum industry showed no indications of improvement in 1941 over 1940. Production, exports, refinery runs, and average price received per barrel all continued to decline, and the refinery output is not only declining in quantity recovered but also in quality. Authoritative sources place the direct annual loss to Mexico by Government operation of this industry to be not less than 50,000,000 pesos per annum. Mexico's annual Federal budget (just published) for 1942 amounts to 550,000,000 pesos and presumably is fairly in line with expected income. Thus the petroleum industry, instead of furnishing additional income, annually costs an amount equivalent to about 10 per cent of the Federal budget.

Russian Oil Industry in 1941

By Basil B. Zavoico,* Member A.I.M.E.

The World War II spread to Russia on June 22, 1941, when the German Armies began their invasion. The Soviet industries, which were already engaged in a tremendous armament program, further accelerated the flow of munitions, and equipment and supplies for all purposes not directly military were either entirely eliminated or reduced to an absolute minimum. With the occupation by German armies of the Dniepr and Kharkov industrial regions, this trend was necessarily further accentuated. The oil industry of Russia, in consequence, was left to rely more and more upon itself, its own very limited manufacturing facilities, extensive repair shops and probably much used equipment out of order stacked in the warehouses. All evidence available to date points to the fact that the new situation not only did not affect the production either quantitatively or qualitatively, but, on the contrary, caused a larger flow of much needed fuels to the country's war machine, primarily by renaissance of both management and labor.

The oil industry of the Soviet Union, left to depend entirely upon itself for equipment and supplies, and even for new workers and technicians to replace those called into the services, did and is still doing a good and effective job. Since it could not hope for new equipment and parts and could not blame any other industry for the delays in delivery, it dragged out old machines from storage and repaired them in its own machine shops. Often such stored and used equipment was but slightly defective, waiting for some small part from factories in Central Russia, plants that now were either in German hands or entirely converted to the manufacture of munitions. More particularly, instead of the pipe that could not be taken to the Caucasus from Central Russia, casing reclaimed from abandoned or submarginal wells was used, or pipe from the abandoned or but slightly used pipe lines; and this practice is being continued even now on a large scale, to create an ample reserve for the duration of the conflict. Indirectly such a development was even an improvement on pre-war days, when many wells about to be completed had to wait for weeks, even months, for the arrival of new pipe, all blame then being placed outside of the industry on the factories in Central Russia. For the purpose of reclaiming equipment and pipe still usable, special crews were organized.

The war also caused much quicker adaptation of certain American practices and introduction of many emergency measures, such as: removal of derricks upon completion of wells and the use of drilling equipment mounted on skids for rapid transfer from location to location—both of these practices, while standard in the U.S.A., being new in Russia; installation of simplified surface pumping units; substitution of wooden bearings in the surface pump equipment; completion of wells in the Ural-Volga district, where formations are hard and tight throughout the sedimentary column, without either casing or

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cement, the wells pumping through tubing (a practice of doubtful value unless fluid levels are very low). Before the war, in many oil fields of the Caucasus gas lift or air lift was widely adopted as the easiest exploitation method, even where such mechanical lifting was entirely unsuited and uneconomical. With the coming of the war, such ineffective lifting was replaced by plunger lifts and deep pumps, with large saving of power and often increase in production. In the refining branch of the industry, production of aviation gasoline and high-test aviation lubricating oils was stepped up very considerably. In the refining of kerosene a new process was developed for manufacture of soap from a naphtha, which has been named "soapnaphtha."

For replacement of technicians and workers called into the services, special training courses were organized, a very large percentage of the number of students being women, often wives of the men called. Thus, in one group of such courses in Leninneft, Baku district, out of 800 students 700 were women.

Under war censorship only a limited amount of information is available on the operation of the Russian oil fields, and the 1941 figures in Table 1 are, therefore, author's estimates. Production of crude oil in the U.S.S.R. during 1941 is placed at 242,250,000 bbl., as compared with 222,600,000 bbl. produced in the preceding year, an increase of 8.83 per cent. The Baku district (Trans-Caucasus) remained the outstanding producing area, accounting for 71.21 per cent of the country's production; the North Caucasus Province, the second in importance, producing 11.76 per cent of the total; followed by the new Ural-Volga region, which accounted for 11.35 per cent of the total U.S.S.R. production.

Apparently there were no developments of major importance in the way of new discoveries in the Trans-Caucasus and the North Caucasus Provinces; in the Ural-Volga district, however, good exploration results are indicated though no details are available.

CONCLUSIONS

The Russian oil industry, because of the tremendous war effort and the resulting enthusiasm of the workers within it, entered, from all evidence available, a period of renaissance that might well shake it out of the pre-war complacency, and which should continue into the post-war period.

But an insignificant proportion of Russian oil production, newly acquired through occupation of eastern Poland, has been lost to the country, all other major provinces being far away from the front lines as of April 1942. The principal oil fields of the Kuban area, producing 41,000 bbl. per day, or 6.91 per cent of the total Russian production, are some 200 miles east from the present Crimean front lines and about the same distance southeast from the front lines at Taganrog. The Grozny fields, producing about 37,000 bbl. per day, or 5.57 per cent of total Russian production, are between 500 and 600 miles southeast from the Taganrog front lines, while the most important Baku district is 800 miles southeast from Taganrog. The principal fields of the Ural-Volga district, producing 75,000 bbl. per day, or 11.35 per cent of Russian production, are 800 miles east from the Smolensk front lines opposite Moscow, the same distance separating the Emba district, producing 12,328 bbl. per day, or 1.86 per cent of the total production, from the southern front. The Turkestan producing base is from 1000 to 2000 miles from the principal battle lines, and though it is of no importance for the industrial regions of Central and Eastern European Russia, that base does supply very important agricultural districts (cotton, vegetable and fruit canning, rubber, etc.) and large Army training camps.

Therefore, it does not appear probable that even if the German Armies should be more successful this year than they were

TABLE 1.—*Production of Crude Oil in Russian Oil Fields from 1931 to 1941*

Year	Total U.S.S.R.,[1] TB[2]	Caucasus										Ural-Volga, Total, $F = 7.19$		All Others									
		Total		Trans-Caucasus, $F^4 = 7.28$		North Caucasus								Total		Emba, $F = 6.97$		Central Asia				Sakhalin, $F = 6.82$	
						Total		Grozny-Dagestan, $F = 7.19$		Kuban, $F = 7.33$								Turkmen, $F = 7.41$		Sredazneft, $F = 7.20$			
		TB	Per Cent[3]	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent	TB	Per Cent
1931	162,146	158,273	97.61	96,229	59.35	62,044	38.26	57,979	35.76	4,065	2.51	43	0.03	3,829	2.36	2,270	1.40	103	0.06	544	0.34	912	0.56
1932	155,078	151,340	97.59	89,089	57.45	62,251	40.14	55,433	35.75	6,818	4.40	75	0.05	3,663	2.36	1,722	1.11	251	0.16	443	0.29	1,247	0.80
1933	155,836	151,379	97.14	111,965	71.85	39,414	25.29	34,959	22.43	4,455	2.86	248	0.16	4,208	2.70	1,369	0.88	1,146	0.74	354	0.23	1,339	0.86
1934	175,727	171,315	97.49	140,088	79.72	31,227	17.77	24,232	13.79	6,995	3.98	535	0.30	3,877	2.21	1,684	0.96	119	0.07	425	0.24	1,649	0.94
1935	182,967	172,807	94.45	141,258	77.20	31,549	17.24	22,793	12.46	8,756	4.79	2,978	1.63	7,188	3.93	1,913	1.05	2,488	1.36	1,155	0.63	1,632	0.89
1936	202,544	187,450	92.55	158,300	78.16	29,150	14.39	21,500	10.61	7,650	3.78	6,844	3.38	8,250	4.07	2,100	1.04	2,850	1.41	1,200	0.59	2,100	1.04
1937	204,150	186,592	91.40	155,792	76.31	30,800	15.09	20,800	10.19	10,000	4.90	7,101	3.48	10,457	5.12	2,900	1.42	3,470	1.70	1,387	0.70	2,700	1.32
1938	219,194	197,494	90.10	161,108	73.50	36,386	16.60	19,236	8.78	17,150	7.82	9,425	4.30	12,275	5.60	3,325	1.52	4,000	1.82	1,600	0.73	3,350	1.53
1939	220,866	194,500	88.06	161,500	73.12	33,000	14.94	15,500	7.02	17,500	7.92	14,016	6.35	12,350	5.59	3,500	1.58	4,000	1.81	1,600	0.72	3,250	1.47
1940	222,600	191,500	86.03	161,000	72.33	30,500	13.70	13,500	6.06	17,000	7.64	18,500	8.31	12,600	5.66	3,750	1.68	4,000	1.80	1,600	0.72	3,250	1.46
1941[5]	242,250	201,000	82.97	172,500	71.21	28,500	11.76	13,500	5.57	15,000	6.19	27,500	11.35	13,750	5.68	4,500	1.86	4,250	1.76	1,750	0.72	3,250	1.34
1941—Barrels per Day[5]	663,698	550,685		472,603		78,082		36,986		41,096		75,342		37,671		12,328		11,644		4,795		8,904	

[1] Refer to Petroleum Development and Technology, *Trans.* A.I.M.E. (1937) **123**, 619, for production figures prior to 1931.
[2] TB indicates Thousands of Barrels.
[3] All percentages calculated to total U.S.S.R. production.
[4] F indicates conversion factor from metric tons into barrels, from average crude gravities in each district.
[5] Author's estimates.

last year, any of the Russian oil fields, with the possible exception of the Kuban area, will be exposed to even air raids. At the same time the present front lines are so far away from the German fuel bases that the problem of transportation is a great handicap to the German Army, while the Russian troops are serviced from oil fields and refineries strategically distributed, with the northern front being supplied largely from the United States through Archangelsk and Murmansk.

Chapter V. Refining

Review of Refinery Engineering for 1941

By Walter Miller,* Member A.I.M.E.

Although confident of its ability to meet any demands that may be made, the petroleum-refining industry is not complacent about the situation and realizes that the quantities of petroleum products to be furnished are so enormous and so far beyond what was previously estimated that the full cooperative effort of the industry must be exerted.

Establishment by the President in May of the Office of Petroleum Coordinator for Defense with Secretary of the Interior Ickes at its head, plus the formation of the Petroleum Industry Council for Defense, in November, provide the channels for united endeavor within the industry and the means for gearing that endeavor in full harmony with the nation's needs. Great strides have been made and a rapid understanding of the situation and the magnitude of the task is being attained by all concerned.

Refining, by constant study and development, by willingness to experiment and install new processes, and to replace older plants with more efficient equipment, had kept on a high plane of efficiency and progress. Working under the free competitive system, it built up its establishments until, as expressed in last year's report, it was easily able to supply any domestic demand that might be placed on it. Turning the United States into the arsenal not only of itself but of the united nations resisting aggression, however, increased the call for practically all petroleum products and in particular 100-octane aviation gasoline and high-viscosity aviation lubricating oils.

Refining Capacity

With over four million barrels a day of crude oil being charged to stills at the year's end, oil refining had broken all records and faced the necessity of further increasing its size to supply the ever-increasing demand for products, some of which, like 100-octane aviation gasoline, were research laboratory curiosities a few years ago. Although the refining capacity of the United States is listed at 4,860,000 bbl., about 800,000 bbl. of this is economically unavailable because of plant location or type. To meet the increasing needs, additional capacity of another half million barrels may have to be built in suitable locations and designed with an eye toward maximum production of aviation gasoline but with inherent flexibility to make it possible to vary and interchange with production of motor gasoline, furnace oils, and other products as necessity dictates. An interesting side light on this refining capacity question was an enquiry from official Washington for knowledge as to any idle refineries of something of the order of 10,000-bbl. daily crude capacity that might be purchased for bodily removal to Russia.

100-Octane Aviation Gasoline

Largest of the tasks confronting refiners at the year's end was that of raising

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100-octane aviation gasoline production to the estimated needs of the constantly growing numbers of combatant planes for 1942 and beyond. With a growth in three years from practically nothing to the present daily output of over 50,000 bbl. of 100-octane gasoline (and a wholesale price change from around a dollar a gallon to one fifth or one sixth as much), refiners had projected and construction was approved on a high-priority basis for more than thirty additional plants for producing its components and the 100-octane-grade fuel.

Refinery engineers and equipment companies had many other plants well along on the drafting boards, construction of which will be carried forward in 1942. Ultimately, enough additional plants should be built to raise the daily capacity to over 150,000 bbl. of 100-octane fuel per day at an installation cost of $150,000,000 to $200,000,000, in addition to investment in existing operating plants.

This grade of gasoline is composed of four basic ingredients: (1) base stock, a light gasoline fraction of suitable boiling range derived either from specially selected crude oil by straight distillation or from catalytic cracking operations or isomerization of pentane and hexane; (2) synthetic high-octane blending agent, principally iso-octane, made either by one of the available alkylation processes or by hydrogenating the product of selective polymerization of isobutene from cracking-still gas; (3) isopentane, with its 90 or so octane value unleaded; and (4) up to 4 c.c. per gallon of tetraethyl lead to reach the 100-octane specification requirement.

In the field of high-octane blending agents, the formation of iso-octane by the catalytic combining of butene and isobutane, using sulphuric acid as the catalyst, has pretty well supplanted the first method used, that of selective polymerization of butene to iso-octane, followed by hydrogenation of the codimer so produced. Lower investment and operating costs, and larger production because of the wider range of cracking-still-gas constituents suitable for alkylating accomplished this change. The operating cost will be further reduced as a result of negotiations between O.P.C. and the group of companies owning the patents and controlling the sulphuric acid alkylation process, which culminated in a royalty reduction of 12¢ per barrel of alkylate made to 30¢ a barrel for civilian operation, a reduction of 21¢ on war production to July 1, 1943, and a further 6¢ lowering at that time to 15¢ on war production. A new step, use of hydrofluoric acid as catalyst, is under development, and two units employing this variation are projected for erection during 1942.

The obvious advantage which high-octane "base" stocks give in higher production of 100-octane gasoline per barrel of alkylate or equivalent spurred the search for wider sources of such material. Light gasoline fractions from selected naturally high-octane crude sources and limitation of such materials to aviation purposes, use of substantial fractions of catalytically cracked gasolines and the catalytic isomerization of the normal pentane-hexane fraction by the newly announced "Isomate Process" of the Standard Oil Co. of Indiana, make possible a downward revision of the earlier estimates of total alkylate needed to reach the 150,000-bbl.-per-day goal for 100-octane fuel. Completion of new catalytic cracking units in 1942, of both Houdry and "fluid catalytic" types, will contribute still further to the supply of high-octane base stocks. These developments mean that something of the order of 60,000 bbl. per day of alkylate and equivalent will suffice for the 150,000-bbl. program instead of the daily 80,000 bbl. visualized earlier.

BUTANE SUPPLY

Members of the butane family are coming into great demand as the alkylation projects mature into operations. Some 50,000 bbl. a day will be needed in the form of butene and isobutane as raw material for the additional alkylate which will be made. Part of this will be supplied by increased production but the full quantity can hardly be secured in that way and stealing from motor gasoline and from "bottled gas" and liquefied petroleum gas fractions will undoubtedly have to be resorted to but probably not until 1943. Any shortage of butene for alkylation purposes that may develop will probably be overcome by catalytic dehydrogenation of normal butane. The latter, available in much larger quantity than either the iso or cracked type, can also be catalytically isomerized to isobutane to the extent necessary.

Maximum possible cooperative effort is being given by oil-company executives and technologists and by the various governmental agencies concerned, all working with and through the Office of Petroleum Coordinator, to this task of increasing 100-octane aviation fuel production.

MOTOR GASOLINE

Early in 1941, before the aviation gasoline problem assumed its present importance, refiners gave renewed attention to increasing antiknock rating of motor gasoline, and for a time the octane race was resumed. Road tests under the auspices of committees of the American Society for Testing Materials, American Petroleum Institute, and the Society of Automotive Engineers indicated that higher octanes were desirable even for older automobiles with initially low octane requirements, because of the gradually greater knocking tendency of engines with long service. To help meet the higher standards several naphtha-reforming installations were made and a considerable number of additional catalytic polymerization units built, with ethyl lead also contributing importantly to the higher standards.

This trend to higher octanes was drastically halted and reversed by the reduction in ethyl lead supplies announced by the Ethyl Gasoline Corporation in November, and to meet that situation the octane numbers of housebrand motor gasolines were reduced by from 2 to 4 numbers by a majority of refiners in most parts of the country. Present indications are therefore that the octane numbers of motor gasolines are to be on a definitely lower level for the duration of the war. Installation of additional catalytic cracking plants of the Houdry and the fluid catalyst processes cannot be depended on to change the picture materially. Their production is needed to offset the octane value lost to motor gasoline by diversion to 100-octane aviation fuel manufacture of high-octane gasoline fractions and other base stocks.

New refineries were added to the extent of about 54,000 bbl. total daily crude capacity, the largest being Continental Oil Company's Lake Charles, La., 10,000-bbl. plant, next in size being the 8,000-bbl. plant of the Douglas Oil Refining Co. in Los Angeles. The latter is noteworthy because of the break into the refining industry of an important aircraft group.

The Lake Charles plant received considerable attention when completed because of the inclusion of many of the most recently developed refining processes into one integrated unit, into which crude is charged and a number of finished products are withdrawn without a break in the operation. The plant includes casinghead gasoline stabilization for butane and isobutane recovery, crude-oil distillation, thermal cracking, naphtha re-forming by the reversion process, thermal polymerization, alkylation, and continuous gasoline sweetening.

LUBRICATING OIL

More evident as the year closed was the large part lubricants will play in industrial production and war activities of the United States and its allies.

Installation during 1942 of a Duo-Sol process solvent-treating plant for the manufacture of aviation lubricating oils by the Standard Oil Co. of California, and another one of the same type and for the same purpose by the Sun Oil Co., plus a new solvent-treating installation announced by the Sinclair Refining Co., and two comparatively small additions to existing equipment will guarantee a definite, substantial increase in manufacturing capacity. Other possible installations are known to be under active consideration with good prospects of consummation, regarding which announcements may be expected during 1942.

Additional capacity will be needed, but it does not appear that apprehension need be felt regarding ability to supply the grade and quantity of lubricants required for aviation purposes, this despite the increasing number of aircraft units coming into active service as a result of the enormous war production plans.

Few now question that solvent-treated oils used in internal-combustion engines require corrosion-inhibiting addition agents, or that oiliness and detergent additives are needed for meeting the load-carrying demands of today's automotive gasoline and Diesel engines. Development work was active, following a prediction made several years ago that lubricating oil would some day consist of a mineral-oil base diluting and carrying small quantities of chemical compounds specifically designed to meet the several requirements for satisfactory service. Highly refined oil is subject to rapid oxidation in high-temperature service, and to formation of organic acids and other deleterious substances. Oxidation inhibitors must therefore be added and also compounds to keep any sludge formed suspended in the oil to prevent formation of engine deposits.

Several new types of such addition agents were introduced commercially during 1941, one of the most successful and widely distributed being a compound having in particular high anti-oxidizing characteristics in connection with other valuable properties, and consisting of a sulphurized olefin synthetically produced employing paraffin wax as a starting material.

Activity in this field is most intense, with evidence of a growth of cooperative scientific and research effort. The further progress and improvement which will certainly result will be effective in better and more efficient lubrication of internal-combustion engines.

WAX, AND SYNTHETIC RUBBER

No new engineering developments have been made in wax production that are worth noting, but the demand and price steadily increased during the year, output also climbing to a high figure. Although no substantial new installations or enlargements of existing facilities have been announced during the year, a number of projects are being actively considered for increasing capacity to supply the greater requirements brought about by the quickening tempo of war production.

Research and development work in the field of synthetic rubber was carried on unremittingly by several organizations without any publicity.

Several enlargements in plant capacity were announced during the year, and new capacity under construction on the day Japan opened war on the United States amounted to about 40,000 tons yearly, in which figure is included the new Neoprene plant nearing completion at Louisville, being erected by the du Pont interests and the Air Reduction Co. of America. This plant is rated at 10,000 tons per year and the erection cost is given as $15,000,000.

The attack on the Netherlands East Indies changed the situation and outlook materially, in spite of the fact that a substantial stockpile had been accumulated which will take care of the most important uses for a year or two.

Shortly after the turn of the new year of 1942, complete control of the manufacture and sale of new tires was taken over by the Government to conserve available supplies to important uses. A program of increasing synthetic rubber manufacture to 700,000 tons a year was instituted with immediate and rapid cooperation being extended by the larger units of the petroleum and tire industries looking toward reaching that goal. A large proportion of the new capacity was definitely projected and negotiations and studies were under way covering most of the balance by Feb. 1, with all industry and government factors working together for a quick solution of this important problem. Butadiene, with a co-polymer, probably styrene, both to be largely produced from petroleum sources, will perforce be the major raw material reliance.

TOLUENE

Estimates of requirements of toluene for the making of T.N.T. have been increased so frequently that the present figures are greatly different from those of a year ago, the quantities now being set for 1943 and 1944 at an ultimate annual rate of four to five times the 60,000,000 gal. talked of in 1940. A comparison in the use of high explosives is afforded by these figures when it is remembered that on the order of 10,000,000 to 12,000,000 gal. was all that was being produced at the peak of the World War No. 1.

Of vital interest to the war effort was the completion and putting into full and successful operation in September of the synthetic toluene plant announced by the Humble Oil and Refining Co. during 1940. The output of the plant is well above the designed capacity of 27,000,000 gal. per year. Shell Oil Co. has two plants operating and one under construction for extraction of toluene naturally present in small but recoverable concentrations in certain crude oils. The total capacity of the three plants will be 8,000,000 gal. A contract has been let for the installation of a plant by another company with a probable output of 7,000,000 gal. per annum.

An interesting development announced during the year was from the manufactured-gas industry and concerned the installation of a battery of Knowles process coking ovens for the destructive distillation of heavy petroleum residues and the manufacture therefrom, in addition to the main objective of city gas, of electrode carbon and various by-product chemicals, including both benzol and toluol. For this plant, the estimated annual production figures list 3,350,000 gal. of benzol and 540,000 gal. of toluol.

The present rate of toluol production by the petroleum industry is estimated at 35,000,000 to 40,000,000 gal., and probably will surpass a rate of 60,000,000 gal. annually by the end of 1942 or at least twice the present-day production of approximately 30,000,000 gal. by the coal-tar industry.

CHEMICALS MANUFACTURE

No one can predict the extent to which the already great chemical industry arising out of oil refining will be expanded by wartime developments and needs, but a tremendous growth will unquestionably take place, in fact is assured. Even now the total of products generally known as chemicals emanating from petroleum raw materials is more than twice the quantity made by the coal-tar industry. This comparison will grow greater as the new plans for production of alkylate for aviation gasoline, of synthetic rubber, of the making of toluene for T.N.T. come into operation.

Research was continued with greater activity and on a broader scale. The industry acquired greater knowledge and skill in manipulating petroleum as a chemical raw material. Laboratory experience of today forms the foundation of development toward large-scale production of tomorrow. New products are in the making but progress of that type was not given publicity and will become known as plants are built and materials made available.

No serious limit exists to the scale of operations of chemical manufacturing based on petroleum-source materials. Witness toluol: 30,000,000 to 35,000,000 gal. a year is the most the coal-tar industry could produce, but from the petroleum industry can come a hundred million gallons, two hundred million, and still more if needed.

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